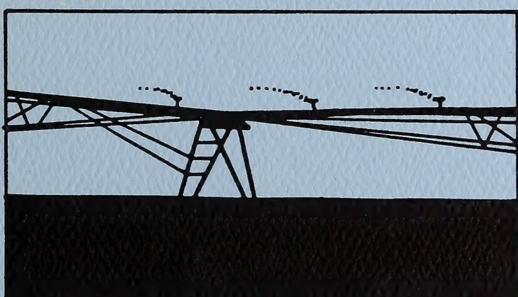
IRRIGATION AND RESOURCE MANAGEMENT DIVISION



Applied Research Report
1994 – 1995

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APPLIED RESEARCH REPORT

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

ALBERTA AGRICULTURE, FOOD AND RURAL DEVELOPMENT

April, 1995

PREFACE

The Irrigation and Resource Management Division Annual Applied Research Report is a collection of progress and final research reports. The research is carried out by staff members of the Division and private consultants retained under contract. Research projects vary from detailed tests to field surveys; from irrigation to conservation topics.

The reports are limited in length and summarize the highlights. The detailed data and information is available from the individual researchers. The reports have been grouped according to subject matter. The authors are responsible for the contents of the report.

Copying of the material is permitted provided credit is given to the researcher(s) and the data and interpretations are not altered.

ACKNOWLEDGEMENTS

I would like to thank the staff members who carried out the research and prepared the reports in this 1994/95 edition of the Applied Research Report of the Irrigation and Resource Management Division. I acknowledge the great effort to plan and carry out these projects, and appreciate the encouragement and support provided by their supervisors.

On behalf of all, I thank the farmers, the irrigation districts, agricultural research organizations, agriculture organizations and the Agricultural Service Boards for their cooperation.

As well, I thank Linda Hansen for reformatting the papers, and Hank VanderPluym and Carly King for compiling and printing the report.

Brian L. Colgan
Director
Irrigation and Resource Management Division

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

APPLIED RESEARCH REPORT - 1994/95

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SOIL SALINIZATION AND YIELD OF SOFT WHEAT IRRIGATED WITH SALINE-SODIC WATER

G. D. Buckland[1], E. de Jong[2], C. Chang[3] and D. Mikalson[1]

INTRODUCTION

Use of saline-sodic water for irrigation increased on the prairies during the 1980's because of increased demand for scare water supplies. Comprehensive irrigation water quality guidelines are developed for arid regions which continuously use saline-sodic waters for irrigation (Rhoades 1982; Ayers and Westcot 1985). In prairie environments, however, rain supplies about half the water requirement of irrigated crops. There is limited evidence that continued use of a saline-sodic water is less damaging to soil structure and permeability than is alternating saline-sodic water with good quality rain (Minhas and Sharma 1986). The introduction of fresh rain to a soil initially equilibrated with a saline-sodic water causes a rapid reduction in the salt concentration (Frenkel et al. 1978), which causes slaking of soil aggregates, swelling and dispersion of soil, with a corresponding reduction in hydraulic conductivity and infiltration rate (Oster and Rhoades 1979; Park and O'Connor 1980). This study was undertaken to determine the effect of alternating different qualities of saline-sodic water with rain on soil salinization and yield of Soft White Spring Wheat (*Triticum aestivum* L. em. Thell, var AC Reed) in an Orthic Brown Chernozemic soil.

MATERIALS AND METHODS

Forty two undisturbed lysimeters, 0.3-m diam. and 1.35-m long, were arranged in a greenhouse in a randomized complete block design. Three soft wheat crops were irrigated with seven qualities of irrigation water alternated with rain using leaching fractions (LF) of 0.05 and 0.10. Irrigation waters ranged in quality from conventional water (electrical conductivity [EC] of 0.3 dS/m and sodium adsorption ratio [SAR] of 0.6 $mmol_c/L^{1/2}$) to highly saline and sodic (EC of 3.0 dS/m and SAR of 20 $mmol_c/L^{1/2}$). Qualities of irrigation waters used are given in Table 1.

Individual lysimeters were irrigated when soil water depletion in the upper 60 cm of soil was 40 mm or more. The first irrigation after seeding used rain (simulated using distilled water), and thereafter saline-sodic waters alternated with rain. Soil water content was determined using time domain reflectometry with waveguides installed at 15- and 45-cm depths and by converting daily readings to volumetric water content using the equation of Topp et al. (1980).

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Table 1. Salinity and sodicity of irrigation waters

EC (dS/m)	SAR ($mmol_c/L$)	Water Classification: Rhoades (1982)	Water Classification: Alta. Agric. (1983)
0.3[z]	0.6	Safe	Safe
1.0	5.0	Safe	Safe
1.0	10.0	Threshold	Threshold
2.0	10.0	Safe	Threshold
2.0	15.0	Safe	Hazardous
3.0	15.0	Safe	Hazardous
3.0	20.0	Safe	Hazardous

[z] Conventional irrigation water

Vacuum extractors were installed in one block of lysimeters to determine changes in salinity and sodicity of the soil solution. After selected irrigations the soil solution was extracted at suctions of 60 to 80 kPa. These samples were analyzed for salinity-related parameters using standard methods (Greenberg et al. 1992).

RESULTS AND DISCUSSION

Salinization and sodification of the soil surface occurred gradually with successive crops (Fig. 1). The increase in soil EC and SAR was proportional to the EC and SAR of the irrigation water used. Native salts in the lower soil solum were leached. Theoretical salinity and sodicity in the soil, shown in Fig. 1, were determined by averaging the concentrations of the irrigation water and rain, and by using the WATSUIT Model (Oster and Rhoades 1990) to predict steady state EC and SAR. More salt needs to be added to the soil, particularly with more saline-sodic irrigation waters, before the soil reaches steady state with the applied irrigation water.

Crop yield characteristics (Fig. 2) were significantly different between crops because of different environmental conditions in the greenhouse. Grain (Fig. 2a) and total dry matter yield (not shown), consumptive water use (Fig. 2b), and water use efficiency (Fig. 2c) were largely unaffected by EC of the water, per se, or LF. This was because of high soil variability (data not shown), possibly because the soil is not in steady state with the irrigation water (Jury et al. 1979), possibly because the resulting salinity is below the threshold tolerance for wheat of about 6 dS/m (Bresler et al. 1982), and possibly because of the high frequency of irrigation which overrides the effect of salt stress.

Crop yield decreased slightly but not significantly in the third crop with irrigation waters of EC 3 and SAR 15 or more (Fig. 2c) compared to other irrigation waters. This is largely because of reduced emergence caused by waters of higher SAR (Fig. 3a). Yields have not been determined for the fourth crop, but crop emergence is lower for waters of EC 3, and is lower for most waters of SAR 10 or more. Reduced or no emergence occurred because the applied rain ponded on the soil surface for

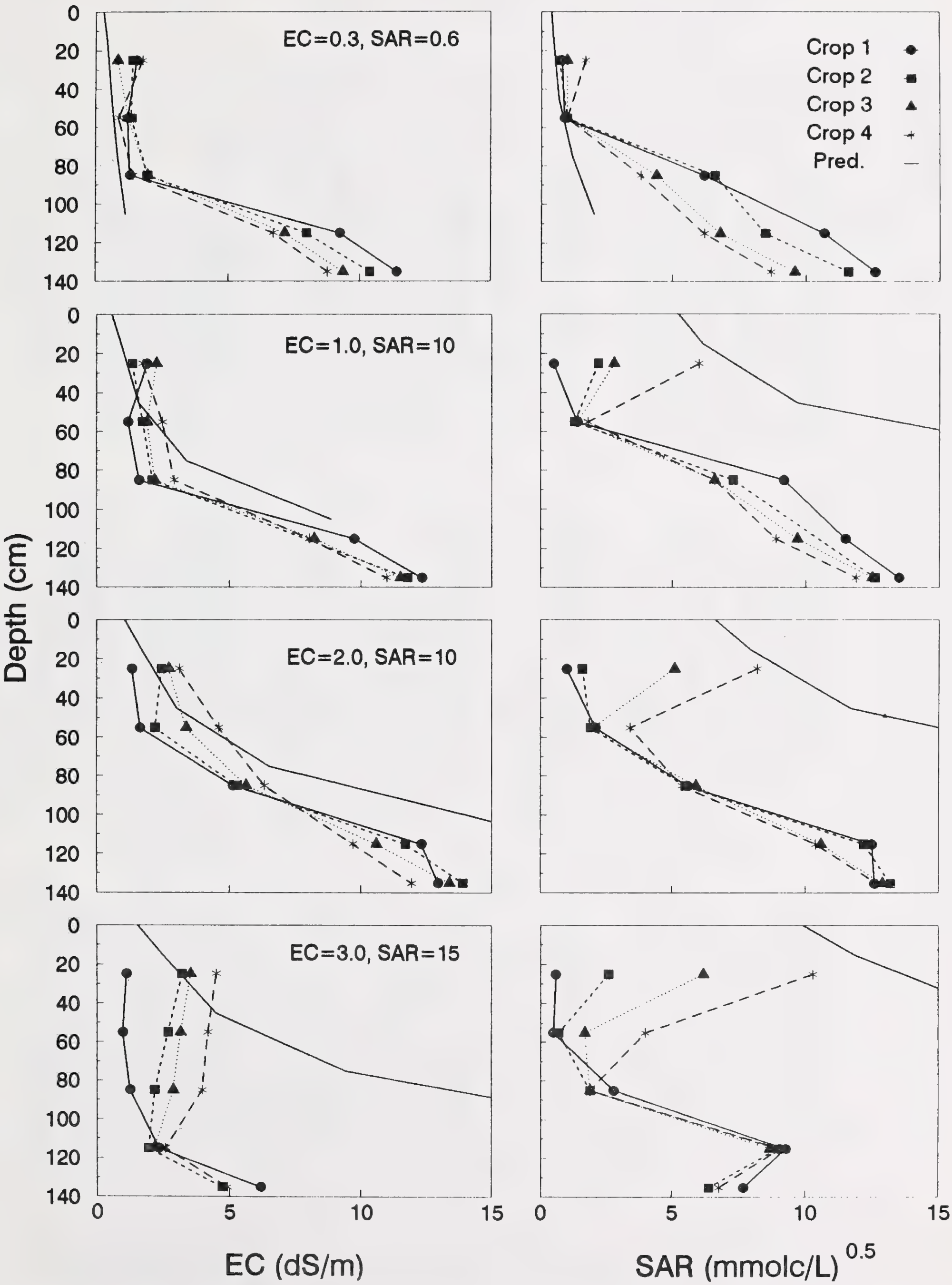

Fig. 1. Changes in salinity (EC) and sodicity (SAR) of soil solution when irrigated with waters of different qualities.

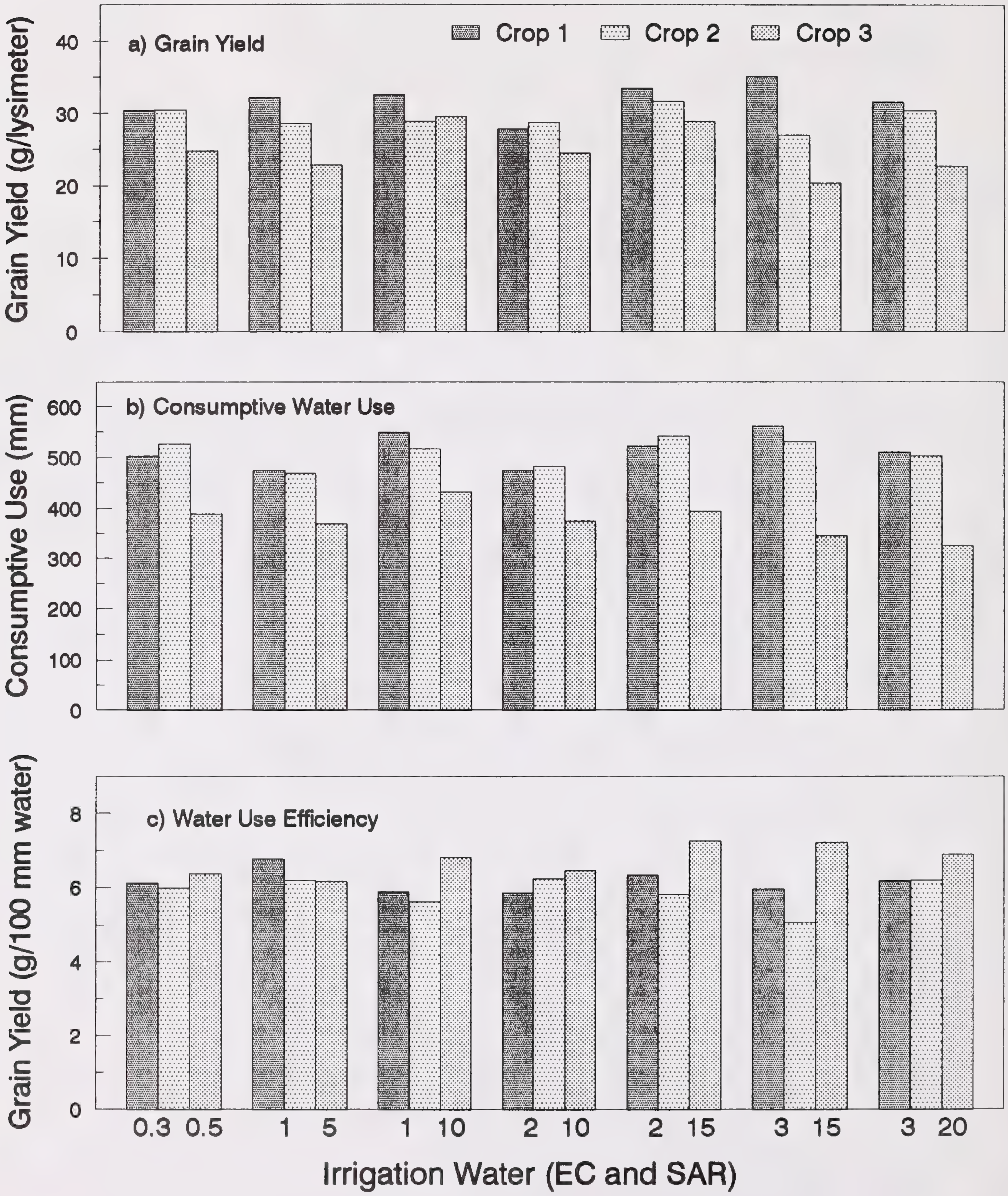

Fig. 2. Crop yield characteristics as affected by saline-sodic waters.

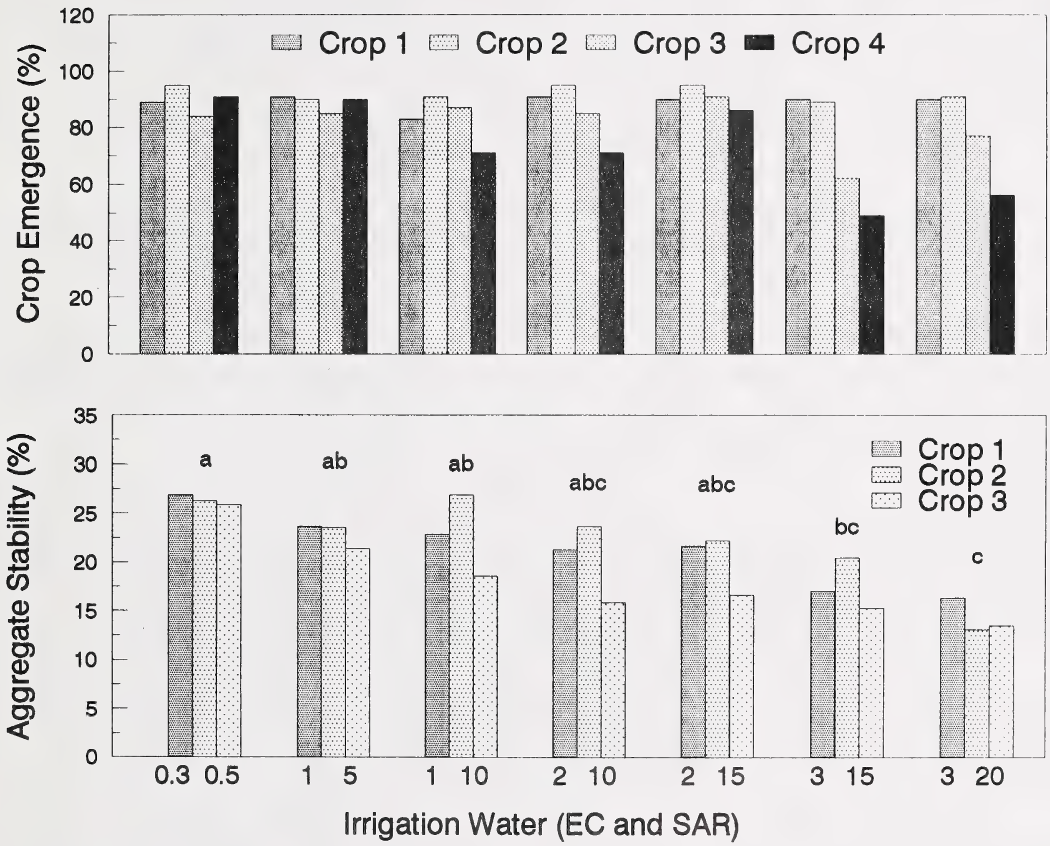

Fig. 3. Crop emergence and aggregate stability as affected by saline-sodic water. (Within irrigation waters, over all crops, means not separated by the same letter are significantly different as determined by Tukey HSD test).

several days which drowned the seed. The observed reduction in emergence is mainly the result of complete crop failure in a given lysimeter rather than a gradual reduction in emergence in all lysimeters.

Stability of soil aggregates decreased significantly with EC and SAR of the applied water (Fig. 3b). This trend roughly paralleled the observed decrease in emergence of crop four with increased salinity and sodicity of the water. This suggests aggregate stability may be useful in screening for poor quality irrigation water.

PRELIMINARY CONCLUSIONS

Preliminary results indicate salinity of the irrigation water will not cause reduced yield of soft wheat during initial years under a high-frequency irrigation regime. This is because salinity levels are only gradually increased with successive crops and levels may be below the threshold for crop tolerance. Crop yield may decrease abruptly because of reduced emergence associated with low infiltration rate and ponding of rain on the soil surface. This is believed to be associated with the SAR of the irrigation water and not the salinity. Aggregate stability may be a promising test for screening irrigation waters for their suitability for irrigation.

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WATER QUALITY MONITORING IN VERDIGRIS LAKE FROM 1991 TO 1994

G. D. Buckland[1], L. B. Kwasny[1] and J. Ganesh[2]

INTRODUCTION

Water quality for irrigation is assessed on two main factors. The salt content of the water is usually measured as the electrical conductivity (EC). Water high in EC causes increasing osmotic stress in plants and this reduces water availability. The sodium hazard of the water is measured as the sodium adsorption ratio (SAR)

$$SAR = Na/(Ca+Mg)^{1/2} \qquad [1]$$

where concentrations of Ca, Mg and Na are in mmol/L. Waters with high SAR tend to cause dispersion in soils, which imparts poor soil structure and reduced permeability to water. At present water with EC < 1 dS/m and SAR < 4 are considered safe for irrigation (Alberta Agriculture 1983). Waters with EC > 2.5 and SAR > 9 are considered hazardous.

Irrigation development along Verdigris Coulee was first proposed in 1978 (Alberta Agriculture 1978). The proposal involved diversion of water from Ridge Reservoir, through Middle Coulee and Verdigris Coulee to Verdigris Lake. Although existing water in Verdigris Lake was higher in salinity and sodicity than water typically used for irrigation, the quality was expected to be suitable when diluted with water diverted from Ridge Reservoir.

Most irrigation developments in Alberta use water of excellent quality. Verdigris Lake, however, has a history of poor quality water. The first diversion of water to Verdigris Lake occurred in 1983. Between 1983 and 1989 water quality Lake generally improved (McMullin and Read 1987; UMA Eng. Ltd. 1991). In 1990 there was an unexpected deterioration in the quality of the water (UMA Eng. Ltd. 1991), for reasons which were not clear. From 1991 to 1994 detailed monitoring of water quality and quantity was undertaken to provide a complete water and salt balance for Verdigris Lake. This would more clearly define the source(s) of salt loading causing changes in water quality within Verdigris Lake.

MATERIALS AND METHODS

Water entering and exiting Verdigris Lake, and EC of water at the lake inlet, were monitored continuously using dataloggers (Fig. 1). On a weekly basis (every two weeks in 1994) water samples were taken at various locations along Verdigris Lake (Fig. 1). Pumping withdrawal, rain and Class A Pan evaporation were also determined weekly (Fig. 1). The lake area and volume were determined using a staff gauge and staging curve for the lake. Flow from Hummels Coulee was provided by

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the Water Survey of Canada. Samples of surface runoff were also taken at selected locations following rains. All water samples were analyzed for EC, soluble Ca, Mg, and Na, pH and SAR using standard methods (Rhoades 1982).

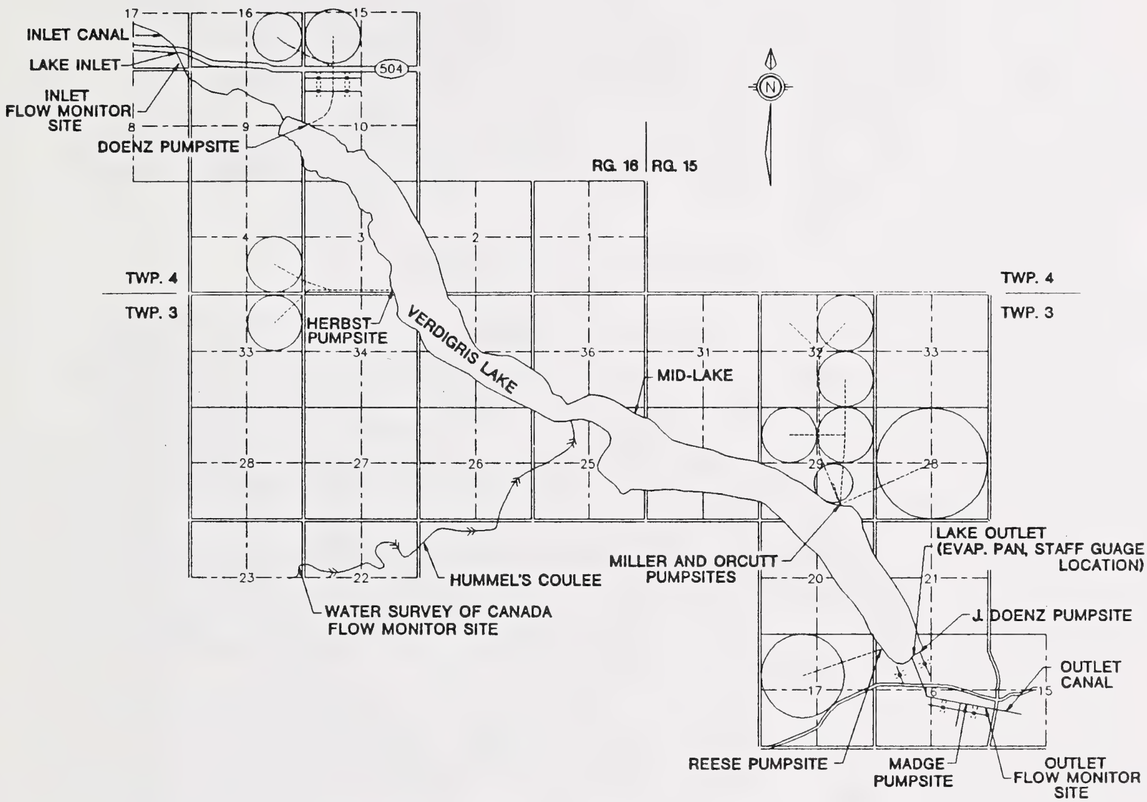

Figure 1. Monitoring locations from 1991 to 1994.

A water balance for the lake was determined for the irrigation season each year using the equation:

$$D_w + R_w - I_w - S_w - E_w = dL_w \qquad [2]$$

where:

D_w = diverted (plus runoff) water entering at the lake inlet;
R_w = rain added over the lake area (excluding runoff);
I_w = water removed from the lake by irrigation;
S_w = water released at the lake outlet as spill;
E_w = water lost from the lake surface by evaporation;
dL_w = change in storage of water in the lake;

The inputs (D_w and R_w) minus the outputs (I_w, S_w, and E_w) equals the change in water storage (dL_w) in the lake provided all inputs and outputs are accurately accounted for. Weekly Class A Pan evaporation was converted to equivalent lake evaporation using a coefficient of 0.7 (Gray 1970).

Salt balance in Verdigris Lake was calculated using the equation:

$$D_wD_s + R_wR_s - I_wI_s - S_wS_s = dL_wS_s \quad [3]$$

where:

D_wD_s = tonnes of salt from diverted (plus runoff) water entering at the lake inlet;
R_wR_s = tonnes of salt from rain added over the lake area (excluding runoff);
I_wI_s = tonnes of salt from water removed from the lake by irrigation;
S_wS_s = tonnes of salt from water released at the lake outlet as spill;
dL_wL_s = change in salt (tonnes) for the lake;

The subscript (s) refers to concentration of solutes. Multiplying a volume of water (eg: D_w) by the concentration of salts in the water (eg: D_s) gives a total mass of salts (ie: tonnes) for that component.

RESULTS AND DISCUSSION

Water quality in Verdigris Lake remained relatively constant during 1991 and 1992 (Fig.'s 2 and 3). In the upper lake the water was usually safe for irrigation (EC < 1, SAR < 4). Water quality at mid-lake hovered around safe levels while that at the lake outlet was consistently above safe levels, with EC usually 1-2 dS/m and SAR > 5. At several times during 1991 and 1992 there was an indication of salt loading from runoff at the lake inlet, as evidenced by sharp increases in EC and SAR of the water at the lake inlet and upper lake sites.

During 1993 and 1994 there was substantial deterioration in water quality throughout the lake. This was most noticeable in the upper lake in 1993. Usually the upper lake is flushed quickly by diverted water but there was sustained high salinity in 1993. By the end of 1994 water quality at the lake outlet was hazardous (EC about 3 dS/m and SAR about 10).

During 1993 waters at the lake inlet frequently had EC's as high as 10 to 14 dS/m compared to the normal EC of about 0.3 dS/m. High salinities occurred following rains and caused a corresponding sharp increase in salt loading of up to 10 times the base loading (Fig. 4). Thus, salt loading from runoff is more important than previously thought (McMullin and Read 1987; UMA Eng. Ltd. 1988). For example, in 1993 about 200 to 300 ac-ft of saline runoff entered at the lake inlet (data not shown). This runoff accounted for 10% of the water entering the lake inlet but was responsible for about 30% of the salt.

Seasonal water balances for Verdigris Lake are given in Table 1. In 1991 and 1992 about 10,000 ac-ft of water was added to the lake as canal inflow, and water removal was largely through evaporation and spill. During these years water quality remained relatively stable. Inlet flows to Verdigris Lake were reduced to under 6000 ac-ft in 1993 and 1994 and during these years water quality deteriorated substantially. Little water was removed by evaporation or irrigation in 1993 because it was an unusually wet year. Evaporation accounted for between 32 and 55 % of the water removals from the lake through all years. This could, in the absence of flows to and from the lake, concentrate salts by 1.4 to 2.2 times.

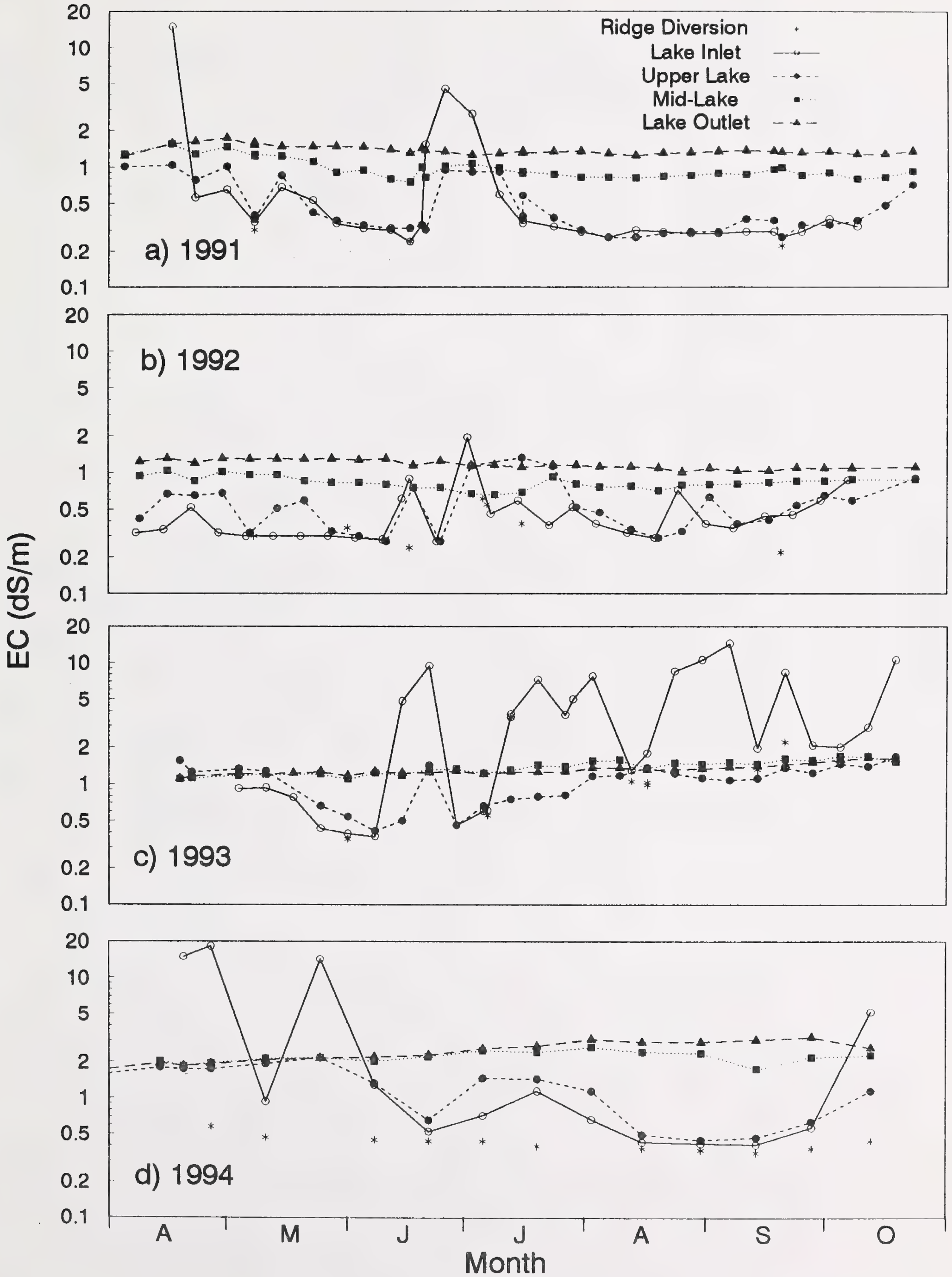

Fig. 2. Electrical conductivity of water along Verdigris Lake.

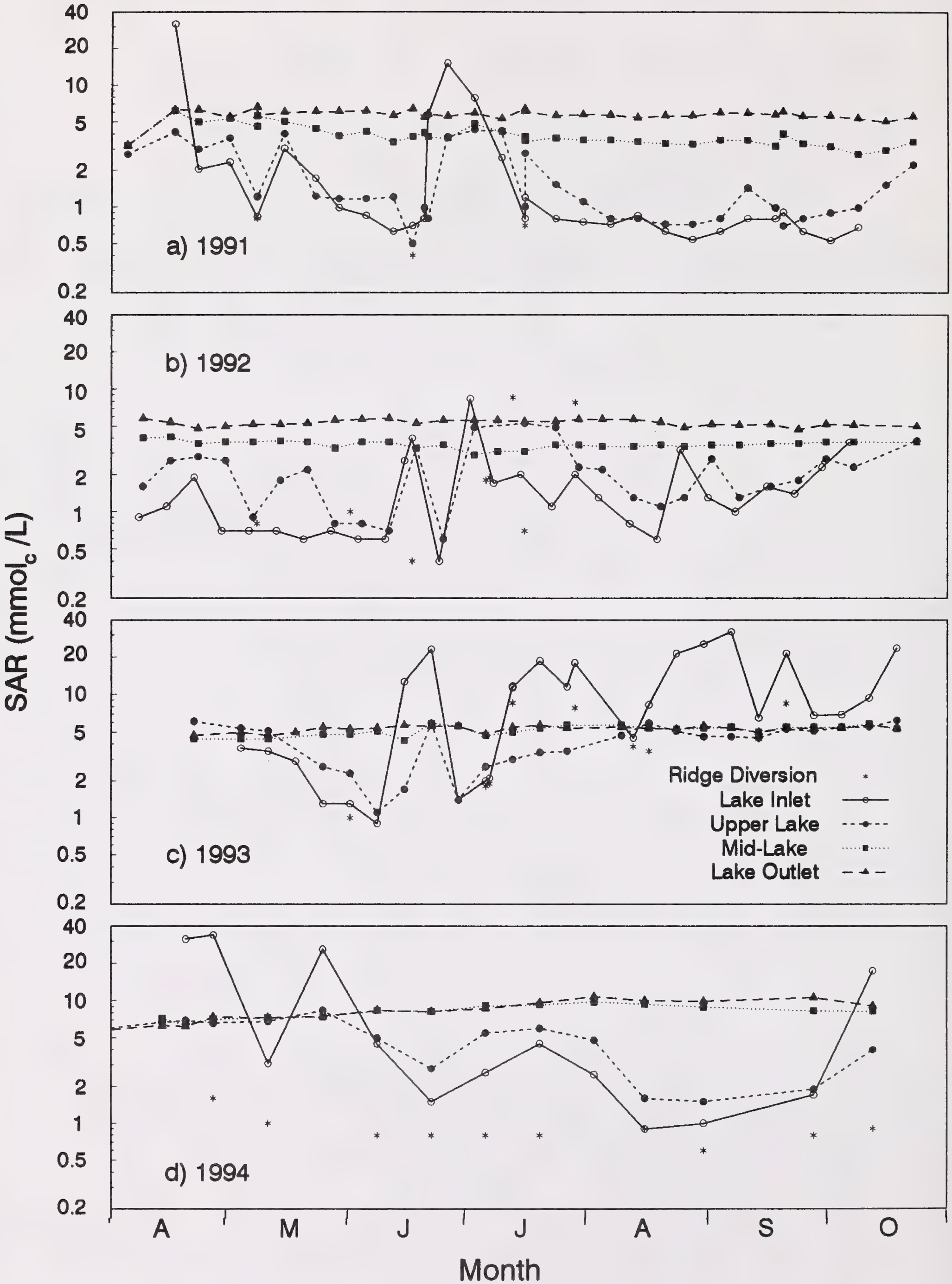

Fig. 3. Sodicity of water along Verdigris Lake.

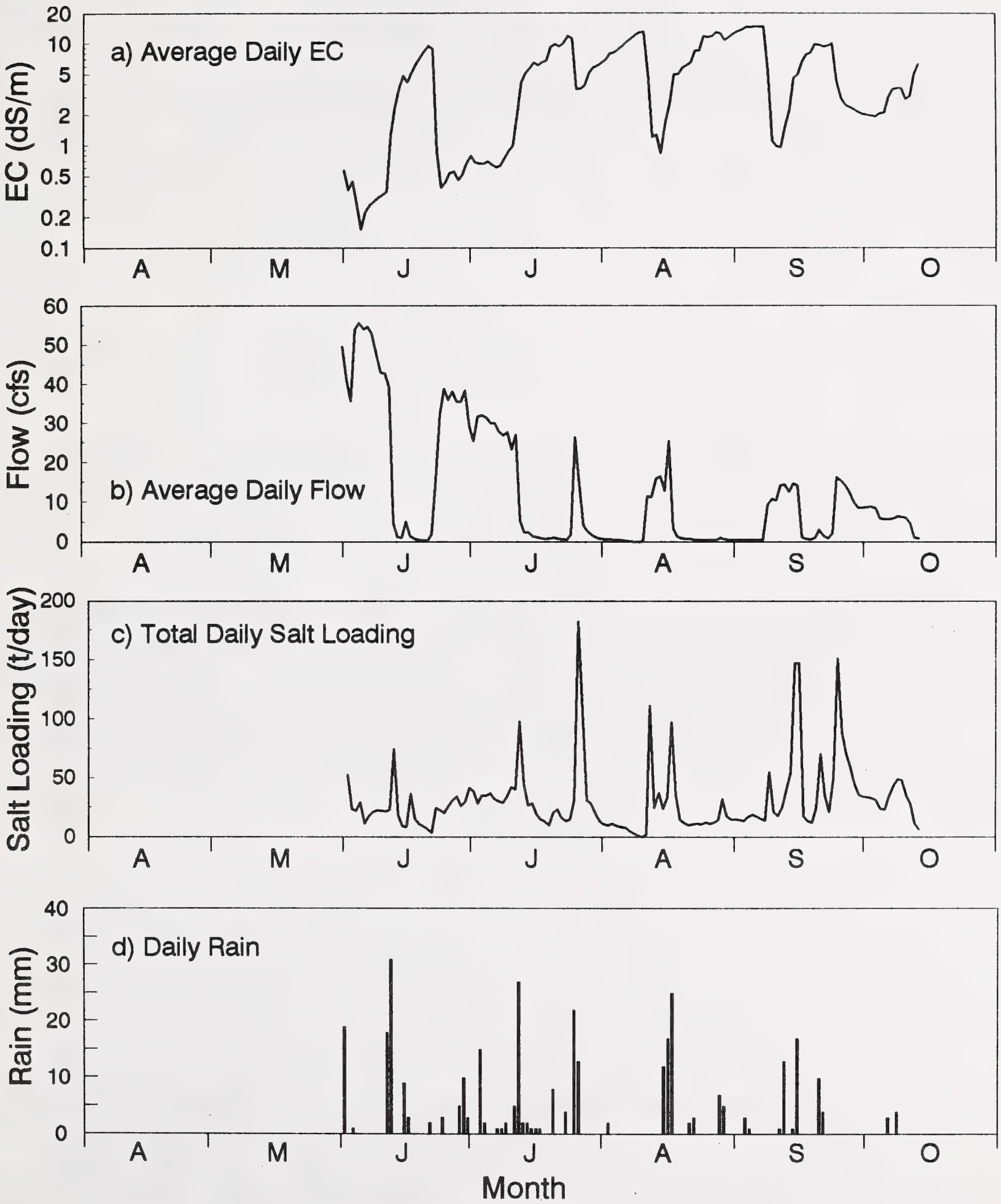

Fig 4. Salt loading at Verdigris Lake Inlet during 1993 in relation to rain.

Table 1. Seasonal water balance for Verdigris Lake (ac-ft)

	Year			
Source	1991 (Apr 23-Oct 16)	1992 (Mar 25-Oct 21)	1993 (Apr 26-Oct 19)	1994 (Apr 20- Oct 18)
Additions				
Canal Inflow	10,250 (82)[z]	9,277 (84)	4,726 (51)	5,478 (82)
Rain	1,348 (11)	1,776 (16)	2,954 (32)	1,103 (17)
Hummels	976 (7)	47	1,668 (17)	92 (1)
Total	12,574	11,100	9,348	6,673
Removals				
Canal Spill	5,671 (47)	4,238 (37)	6,443 (62)	2,987 (30)
Evaporation	4,524 (38)	5,255 (45)	3,336 (32)	5,365 (55)
Irrigation	1,785 (15)	2,150 (18)	609 (6)	1,451 (15)
Total	11,980	11,643	10,388	9,803
Change in Storage	594	-543	-1,040	-3,130

[z] Values in brackets give additions or removals as % of total.

Seasonal salt balance (Table 2) indicates salts were removed from Verdigris lake in all years. Removal of 2,400 (1992) to 4,700 (1991) t of salt in the lake should have resulted in an average reduction in EC between 0.3 and 0.6 dS/m. This, however, is not consistent with steady or increasing salinity observed over the four years, especially in 1993 and 1994. This is partially attributed to water influx from Hummels Coulee, which was accounted for in the water balance but not in the salt balance. Selected runoff samples from Hummels Coulee had EC's ranging from 2 to 19 dS/m.

CONCLUSIONS

Water quality in Verdigris Lake remained nearly constant in 1991 and 1992, and deteriorated substantially in 1993 and 1994. Salt balance indicated water quality should have improved in all years. Saline runoff water, entering the lake via the inlet canal, is partially responsible for water quality deterioration. Runoff water entering from Hummels Coulee likely also contributed to water quality deterioration.

Total diversions to Verdigris Lake of 10,000 ac-ft per year resulted in near stable water quality but lower diversions, and runoff during a wet year (1993), resulted in substantial deterioration in water quality. Evaporation removes about one-third to one-half the volume of the lake and this, in the absence of water diversions, would concentrate salts by 1.4 to 2.2 times their initial concentration.

Table 2. Annual salt balance for Verdigris Lake (tonnes)

	Year			
Source	1991 (Apr 23-Oct 16)	1992 (Mar 25-Oct 21)	1993 (Apr 26-Oct 19)	1994 (Apr 20- Oct 18)
Additions				
Canal Inflow	3,677 (99)[z]	3,588 (99)	5,016 (98)	6,352 (99)
Rain	40 (1)	53 (1)	88 (2)	33 (1)
Total	3,717 (7)	3,641	5,104	6,385
Removals				
Canal Spill	7,035 (84)	4,429 (74)	7,859 (93)	6,834 (71)
Irrigation	1,375 (16)	1,578 (26)	580 (7)	2,761 (29)
Total	8,410	6,007	8,439	9,595
Change in Salt	-4,693	-2,366	-3,335	-3,210

[z] Values in brackets give additions or removals as % of total

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The authors thank Don Roth for collecting flow data, Dennis Mikalson for collecting EC, rainfall and salt loading data for the Lake Inlet, and Marvin Marose and Alec Szentes for collecting weekly water samples, rain and evaporation data. Water samples were analyzed by Soil and Water Laboratory staff. We are grateful to the irrigators along Verdigris Lake who supported the monitoring reported here.

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MONITORING OF SOLONETZIC SOILS UNDER IRRIGATION NEAR SUNNYNOOK (YEAR TWO - 1994)

F.J. Hecker, D.R. Bennett, T.M. Peters, P. Graveland[1]

INTRODUCTION

This report is a summary of year two of a three-year monitoring study. The objectives of this study are:

1) To determine the crop production capability of Chernozemic and Solonetzic soil associations under existing irrigation management practices.
2) To assess changes in salinity and sodicity.
3) To evaluate the irrigation suitability of the irrigated Solonetzic soils in light of the irrigation management regime.

The study site is located in the NW 26 and SW 35-027-12-W4 along Berry Creek near Sunnynook in east-central Alberta. A level II land classification for irrigation was completed within SW 35 in 1985 and NW 26 in 1990 according to the 1983 standards (Alberta Agriculture 1983). Approximately 40% of the proposed pivot area was rated irrigable (Fig. 1) (Greenlee et al. 1994). This portion contains mainly Chernozemic soils. Approximately 60% was rated nonirrigable due to the dominance of Solonetzic soils. A 54 ha (133 ac) pivot was set up in 1990. Irrigation started during the 1991 crop season under a temporary water license issued by Alberta Environmental Protection with the stipulation that the soils be monitored.

METHODS

Soil profiles were described and sampled on a 50 by 50 m grid within the pivot area in the fall of 1992 (Greenlee et al. 1994). Results were used to check the level II land classification and to select six plots for detailed soil and crop monitoring. The more intensive investigation confirmed the distribution of soils on the original level II land classification maps.

Three 10 m by 10 m plots were located within each of the Solonetzic and Chernozemic landscapes (Fig. 1). Soils were described and sampled in the four corners of each plot in the fall of 1992 to characterize the soils prior to monitoring. Soils were sampled again in 1993 and 1994 after the crops were harvested to assess changes in soil chemistry over time. Soil samples were taken from the A, B, upper C and lower C horizons to a depth of 1.2 m. Soil pH, electrical conductivity (EC_e) and soluble cations from the saturated paste extract were determined (Rhoades 1982), and the sodium adsorption ratio (SAR) was calculated.

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Replicate mean values for each soil chemical parameter and each soil horizon sampled in 1992 were analyzed statistically to assess the uniformity of treatments (Greenlee et al. 1994). A split-plot analysis of variance, with time as the split, and protected least significant difference test were conducted for each soil chemical parameter within each sampling depth for 1992, 1993 and 1994. The statistical tests were completed to determine whether significant changes in pH, EC_e and SAR had occurred in the Solonetzic and Chernozemic soils over time and to assess differences between the two soil types.

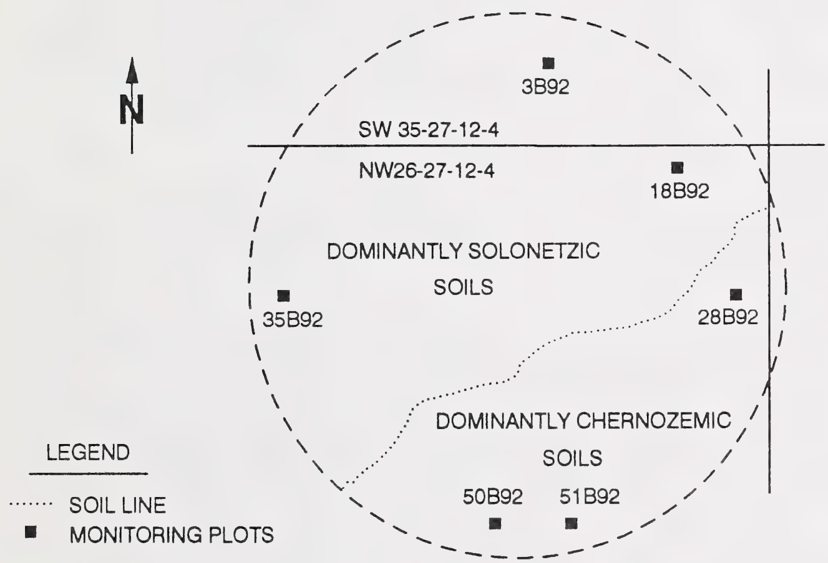

Figure 1. Location of plots within pivot circle.

One 3 m deep water table well and two 1.5 m long neutron probe access tubes were placed within each plot to monitor shallow water table fluctuations and soil moisture content in response to irrigation and precipitation events (Greenlee et al. 1994). Deeper (5.7 to 9.2 m) water table wells and piezometers were installed within one Chernozemic plot and all Solonetzic plots in 1994 to check for any deeper groundwater. One 5.6 m deep water table well was installed north of the pivot circle in the Solonetzic landscape on native range.

The pivot area was seeded with a mixture of Bonanza barley (80%) and Grizzly oats (20%) in 1993 (Greenlee et al. 1994) and Duke barley (89%) and Grizzly oats (11%) in 1994. A fertilizer blend of 46-0-0 (179 kg ha^{-1}) and 11-51-0 (56 kg ha^{-1}) was broadcast in 1993 and a herbicide was applied to control weeds. Solonetzic plot 35B92 was not fertilized in 1993 because the pivot stood over the plot during the fertilizing operation (Greenlee et al. 1994). A fertilizer mixture of 46-0-0 (224 kg ha^{-1}) and 11-51-0 (90 kg ha^{-1}) was broadcast in 1994 prior to seeding. A herbicide for weed control was not applied in 1994.

A tipping-bucket rain gauge was installed in one Chernozemic and one Solonetzic plot, in addition to a manual rain gauge on each plot, to record precipitation and irrigation events. A tipping-bucket rain gauge was also installed outside the pivot to record precipitation. Irrigation water was sampled three times during the 1994 irrigation season and was analyzed for pH, EC, and soluble cations (calcium, magnesium, sodium, and potassium). SAR was also calculated.

Crop samples were obtained from the four corners of each plot on August 11, 1993 (Greenlee et al. 1994). Crops were sampled on August 23, 1994, by cutting a 0.9 m swath along two opposite sides of each plot with a sickle mower. Samples were gathered into burlap bags, weighed and dried in a hot-air drying room. The total dry matter was calculated. Samples were then threshed with a small plot threshing machine. The grain was weighed, cleaned and a net grain yield calculated. Plot mean values for crop yield were analyzed using an analysis of variance statistical model and a protected least significant difference test.

PRELIMINARY RESULTS AND DISCUSSION

Crop Yield

No significant difference in mean crop yield was detected between the Chernozemic and Solonetzic plots in 1993 or 1994 (Table 1). Yields, however, were higher in 1994 than in 1993.

Table 1. Comparison of mean barley yield from Chernozemic and Solonetzic plots in 1993 and 1994[z]

Plot	Total Dry Matter $t\ ha^{-1}$ ($ton\ ac^{-1}$)		Grain Yield[y] $kg\ ha^{-1}$ ($bu\ ac^{-1}$)	
	1993	1994	1993	1994
		CHERNOZEMIC PLOTS		
28B92	7.1 (3.2)	14.5 (6.5)	3170 (59)	3490 (65)
50B92	9.9 (4.4)	17.5 (7.8)	3680 (68)	4130 (77)
51B92	10.6 (4.7)	14.2 (6.3)	3180 (59)	3810 (71)
Average	9.2 (4.1)	15.4 (6.9)	3343 (62)	3810 (71)
		SOLONETZIC PLOTS		
3B92	9.5 (4.3)	10.4 (4.6)	3240 (60)	3720 (69)
18B92	5.9 (2.6)	15.7 (7.0)	2530 (47)	3820 (71)
35B92[x]	--	19.2 (8.6)	--	3720 (69)
Average	7.7 (3.3)	15.1 (6.7)	2885 (54)	3753 (70)

[z] Yields between treatments were not significantly different at $p < 0.01$ or $p < 0.05$, as determined by a protected least significant difference test.
[y] The $bu\ ac^{-1}$ yields were calculated using a grain weight of 48 $lb\ bu^{-1}$.
[x] Yield for plot 35B92 not used in 1993 because it had not been fertilized.

Irrigation and Precipitation

Between seeding and plot harvest in 1993, a total of 251 mm of moisture was applied, consisting of 74 mm of irrigation water and 177 mm of precipitation (Greenlee et al. 1994). A total of 286 mm of moisture was applied in 1994, including 143 mm of irrigation water and 143 mm of precipitation (Fig. 2). The mean pH, EC (dS m^{-1}) and SAR of the water was 7.8, 0.58 and 2.2, respectively. This water is considered safe for irrigation (Alberta Agriculture 1992).

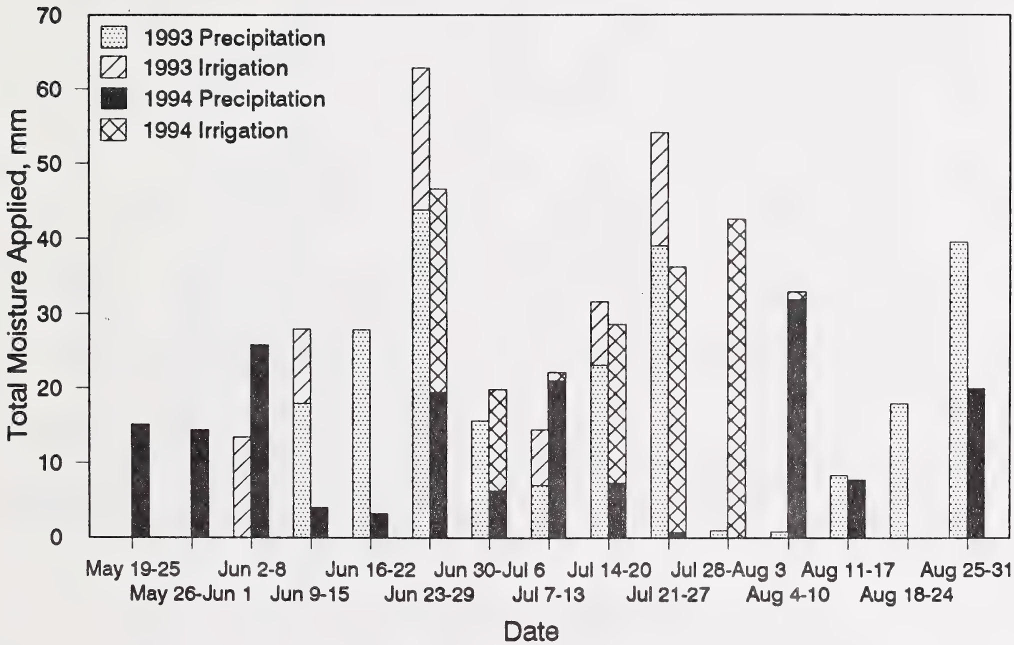

Figure 2. Growing season irrigation and precipitation for 1993 and 1994.

Soil Chemical Parameters

Greenlee et al. (1994) found that the pH of the B horizon; EC_e of the B, C1 and C2 horizons; and SAR of the A, B, C1 and C2 horizons were significantly and consistently higher in the Solonetzic soils than in the Chernozemic soils in 1992, prior to the start of the monitoring program. This trend continued in 1993 and 1994. The only exception was pH of the C1 horizon, which was significantly higher for Solonetzic soils than for Chernozemic soils in 1993 and 1994 (Table 2, 3 and 4; Fig. 3). A significant increase in soil pH in the B, C1 and C2 horizons was detected in 1994 (Table 2).

Greenlee et al. (1994) reported a significant decrease in soil salinity and sodicity within the A horizon of soils in each treatment from 1992 to 1993. This was attributed to leaching from the abnormally high precipitation, in addition to irrigation,

Table 2. Comparison of soil pH for Chernozemic and Solonetzic soils from 1992 to 1994[z]

Horizon	Soil	pH			
		1992	1993	1994	Mean
A	Chernozemic	6.5	6.7	6.4	6.5 a
	Solonetzic	6.2	6.4	6.2	6.3 a
	Mean	6.4 m	6.5 m	6.3 m	
B	Chernozemic	6.8	6.8	7.2	6.9 a
	Solonetzic	7.6	7.4	7.8	7.6 b
	Mean	7.2 m	7.1 m	7.5 n	
C1	Chernozemic	7.5	7.7	7.8	7.7 a
	Solonetzic	8.0	8.2	8.2	8.1 b
	Mean	7.8 m	8.0 n	8.0 n	
C2	Chernozemic	7.8	7.8	8.1	7.9 a
	Solonetzic	7.8	8.0	7.9	7.9 a
	Mean	7.8 m	7.9 mn	8.0 n	

[z] Mean values for each soil followed by the same letter are not significantly different at $p < 0.05$.
Mean values for each year followed by the same letter are not significantly different at $p < 0.05$.

Table 3. Comparison of soil EC_e for Chernozemic and Solonetzic soils from 1992 to 1994[z]

Horizon	Soil	EC_e, dS m^{-1}			
		1992	1993	1994	Mean
A	Chernozemic	1.03	0.56	0.73	0.77 a
	Solonetzic	1.11	0.77	1.13	1.00 a
	Mean	1.07 m	0.77 n	0.93 m	
B	Chernozemic	0.81	0.84	0.62	0.76 a
	Solonetzic	1.85	1.58	1.36	1.60 b
	Mean	1.33 m	1.21 m	0.99 m	
C1	Chernozemic	1.01	1.49	1.16	1.22 a
	Solonetzic	3.42	3.72	3.99	3.71 b
	Mean	2.21 m	2.60 m	2.58 m	
C2	Chernozemic	1.38	1.94	1.35	1.56 a
	Solonetzic	5.34	5.91	6.89	6.05 b
	Mean	3.36 m	3.92 m	4.12 m	

[z] Mean values for each soil followed by the same letter are not significantly different at $p < 0.05$.
Mean values for each year followed by the same letter are not significantly different at $p < 0.05$.

during 1993. This trend appeared to reverse in 1994. The EC_e and SAR of the A horizon was significantly higher in 1994 than in 1993, but not significantly different from 1992 (Table 3 and 4).

Table 4. Comparison of SAR for Chernozemic and Solonetzic soils from 1992 to 1994.[z]

Horizon	Soil	SAR			
		1992	1993	1994	Mean
A	Chernozemic	2.00	1.20	2.03	1.74 a
	Solonetzic	4.53	3.33	4.80	4.22 b
	Mean	3.27 m	2.27 n	3.42 m	
B	Chernozemic	1.10	1.37	1.47	1.31 a
	Solonetzic	10.77	8.27	9.70	9.58 b
	Mean	5.93 m	4.82 m	5.58 m	
C1	Chernozemic	0.90	1.07	1.03	1.00 a
	Solonetzic	12.43	12.07	12.07	12.19 b
	Mean	6.67 m	6.57 m	6.55 m	
C2	Chernozemic	2.57	1.93	2.17	2.22 a
	Solonetzic	11.93	11.63	10.80	11.55 b
	Mean	7.25 m	6.78 m	6.48 m	

[z] Mean values for each soil followed by the same letter are not significantly different at $p < 0.05$.
Mean values for each year followed by the same letter are not significantly different at $p < 0.05$.

ACKNOWLEDGEMENTS

Appreciation is expressed to Irrigation Branch, Brooks, partners in this project, especially David McKenzie, Joanne Bakker and Greg Snaith, for cooperation and assistance in collecting data, and to Mr. David Kingcott, landowner, for his cooperation. Thanks also to the Alberta Special Crops and Horticultural Research Centre, Brooks, for use of their crop-drying room and threshing machine.

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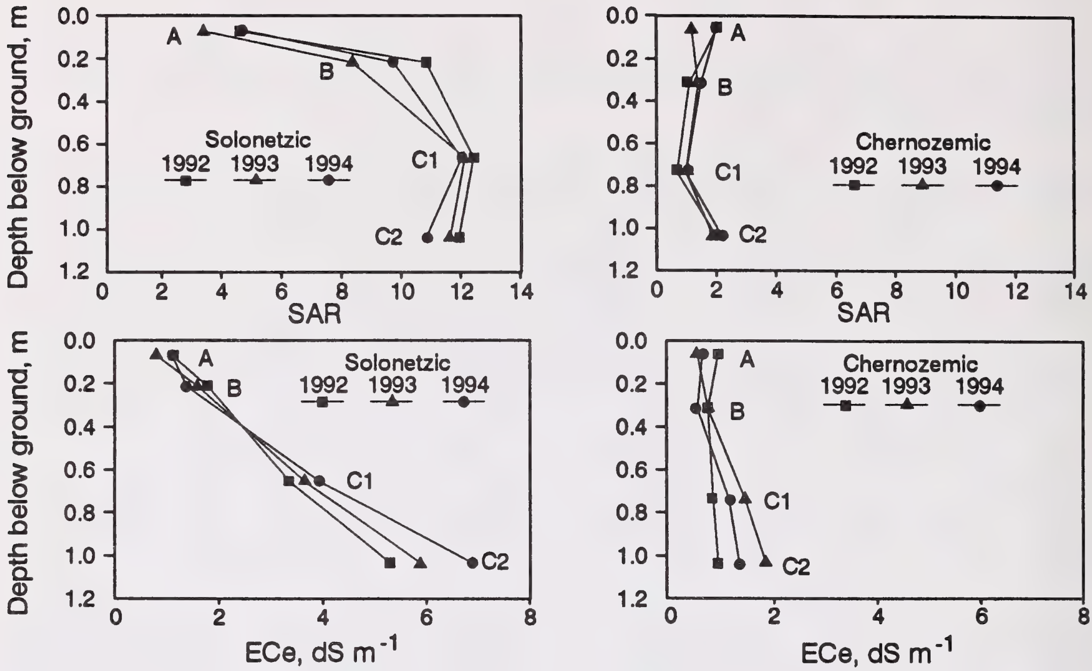

Figure 3. Mean EC_e and SAR of the A, B, C1 and C2 horizons for the Chernozemic and Solonetzic soils.

IRRIGATION - WATER APPLICATION

IRRIGATION BLOCK STUDY

Jack Ganesh, P.Eng.[1] and Bob Riewe, P.Ag.[1]

INTRODUCTION

In May 1990, Alberta announced a water management policy for the South Saskatchewan River basin which established guidelines for irrigation expansion. The announcement stated that "these guidelines for limiting irrigation expansion will be reviewed in the year 2000". In order to make proper water management decisions, accurate and complete information regarding water supply, crop water use, and return flow databases for the irrigation districts is required.

The current review process of the Water Resources Act has highlighted many policy issues with potential implications for water management within the irrigation districts. This new water management policy reflects the increasing pressure on the resource. Irrigation is the largest licensed use of water in the province and is often perceived by the public and many policy makers to be wasteful and beneficial to only a small group of people. In reality, the benefits are more general to the province and the country as a whole.

The study involves five components:

1. To collect field data to calibrate the Irrigation District Model for both irrigation districts at their present levels of on-farm and district management.

2. To test the accuracy of the Irrigation District Model (I.D.M.) and calibrate it against actual field data collected from two irrigation blocks.

3. From the detailed block study, evaluate the irrigation districts' present water allocation criteria.

4. To develop and test new management strategies to manage inflow, reduce return flows, and improve on-farm use.

5. To determine the quality of water entering and leaving two irrigation blocks, and returning to the rivers.

<u>Project Locations:</u>

<u>B.R.I.D.</u>

The Block selected is located approximately 15 km. northwest of the Town of Vauxhall. The block selected is known as K-5 which completely rehabilitated in 1991. The laterals are PVC-lined with gravel armour, new farm turnout structures and new check and drop structures.

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This block is 3359 acres in size, made up of 1853 acres (58.1%) of surface irrigation (primarily border dyke), and 1506 acres (41.9%) sprinkler irrigation. The area being irrigated by sprinklers is made up of 811 acres (53.6%) of centre pivots and 695 acres (46.4%) of side wheel roll.

L.N.I.D.

The Block under study is located near the Town of Iron Springs. The block is known as Lateral J12, which was rehabilitated in 1985. The majority of the lateral is lined with reinforced concrete. As part of the canal rehabilitation, new check and drop structures were installed. The end portion of the lateral is earth lined. There is only one parcel of land which is surface irrigated, the balance is sprinkler irrigated.

METHODS

B.R.I.D.

In the spring of 1994, all remaining stilling wells were installed. A total of 15 lateral and drains sites were monitored. Figure #4 outlines the locations of the stilling wells. Dataloggers complete with water level equipment was installed prior to water entering in to the system. Water was available in the block May 4th.

Steel plates were installed on 3 drop structures located on drains. These plates form "V" Notch weirs for a depth of 1 ft and a combination "V" Notch and Rectangular Weir for higher flows. With the flow of water in drains to be very small for most of the crop growing season, the "V" Notch will ensure a high level of accuracy. Higher flows can be accommodated by the combination "V" Notch and Rectangular weirs also ensuring a high level of accuracy.

16 Cutthroat flumes were installed in the spring of 1994 in farm head ditches. Two Cutthroat flumes were installed in the spring of 1993. Figure #5 outlines the locations of the Cutthroat flumes in farm head ditches. For each Cutthroat flume installed, two stilling wells were also installed. The stilling wells contain the same water levelling equipment found in the district works. These wells are required to measure the height of water entering and leaving the flume. Propeller flow meters have been installed on 10 sprinkler systems.

An automated weather station has been set up in the centre of the project area to collect temperature, solar radiation, rainfall, relative humidity, and wind travel data.

L.N.I.D.

In the spring of 1994, L.N.I.D. installed a broad crested weir just down stream of the turnout from the main canal. A stilling well was also installed at this site. The L.N.I.D also installed 2 stilling wells located in district drains and three stilling wells in farm delivery ditches.

Most of the flow metering equipment for the sprinkler systems has been purchased. Flow meters are to be installed in the spring of 1995, prior to the start of the irrigation season. Where flow meters are not practical, hours meters will be used to determine the amount of time the irrigation farmers was operating their system.

RESULTS
(B.R.I.D. only)

The major crops grown in the project area are cereals and forages. Cereals account for 60.1% and forages 18.2% of the total acres. Figure #1 gives the breakdown on a percentage basis for crops grown in the project area.

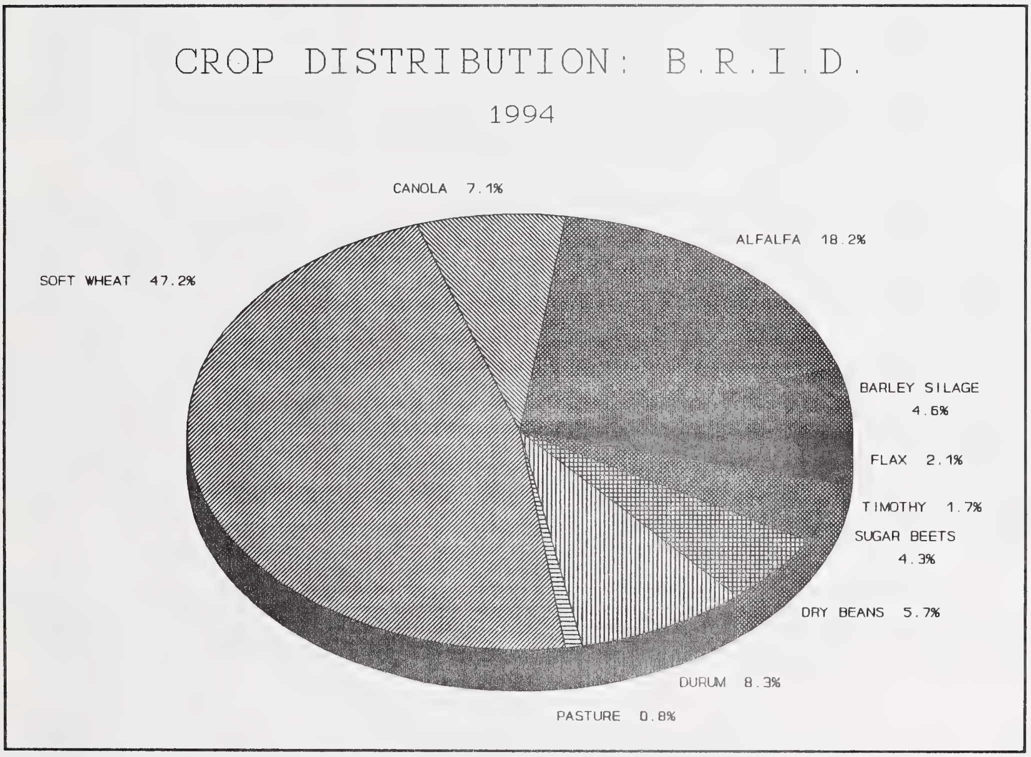

Figure 1: Crop Distribution for B.R.I.D

From April 15th to the end of October, 195.1 mm of rainfall had been recorded for the area. The 30-year average for the area is 223 mm.

In 1994, the flow of every side roll and centre pivot was measured, using a portable flow meter. Field results indicate that side roll systems had an average flow of 955 U.S g.p.m. and centre pivots 934 U.S. g.p.m . Gravity irrigated fields received 2075 U.S.g.p.m. per turnout. Flow for gravity irrigated fields was determined using cutthroat flumes installed in each head

ditch prior to the start of the irrigation season.

Irrigation District Model:

In 1994, the actual gross diversion of water into the block was 7027.1dam^3 and return flow was 2577.4 dam^3.

Once all of the data was compiled and entered in to the Irrigation District Model, the theoretical values calculated follow a similar trend compared to the actual data. Figures #2 and #3 compare field results to calculated values. The model has the ability to calculate inflow and return flow using either the fraction or average method. The fraction method estimates a constant value of return flow through out the run time period of the model. The fraction method is based on the base flow set for the lateral. The average method assumes that the ditchrider predicts the demand several days ahead and adjusts the flow several days in advance. In doing so, the excess flow not being used becomes return flow. If the ditchrider does this throughout the season until peak demand is reached, there will always be excess water which will show up as return flow. If there is any rainfall during this time, farmers have a tendency to shut down their systems increasing the return flow. In reducing flow from the peak demand, adjustments to return flow are made only when the excess flow is appreciable.

In comparing the average method to the actual data, this method over estimates demand flow by 32.3% (2267dam^3) and under estimated return flow by 1.8% (47.6dam^3). The fraction method over estimated demand flow by 39.5% (2772.3dam^3) and return flow by 17.6% (452.9dam^3).

For both graphs showing inflow, the model shows an early spike in the crop growing season compared to the actual field data. The spike occurs because the model is set up to start calculating crop consumptive use when there are 5 consecutive days above 5°C after the 15th of April. In the block study area, 18.2% of the acres are in alfalfa. If the weather is favourable, alfalfa will begin to grow mid April. In most cases, Irrigation Districts are not prepared to deliver water to the farm gate before mid May.

At the present time, this model does not have the ability to address/calculate fall irrigation. Both inflows graphs show a rise in demand for water in the fall where the model does not. This is one area that Alberta Environmental Protection is working on to correct this limitation.

CONCLUSION

With only one year of data available, the model has a severe tendency to over estimated demand. At the present time, we are unsure of why this is occurring. The average method for estimating return flow is quite accaurate. The authors are unsure of what the influence block size on the model and which method should be used for calculating demand and return flow.

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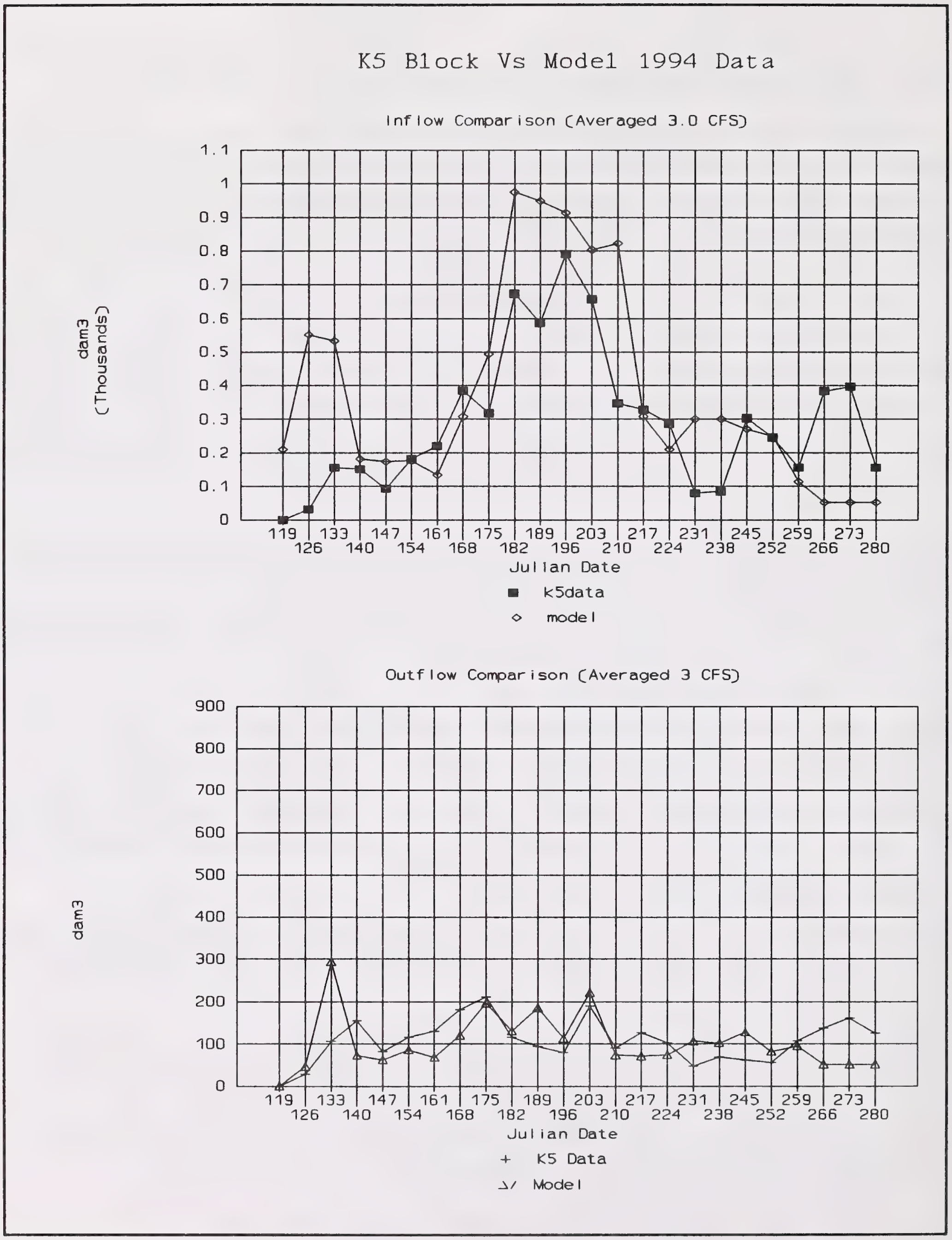

Figure 2: Averaged Method

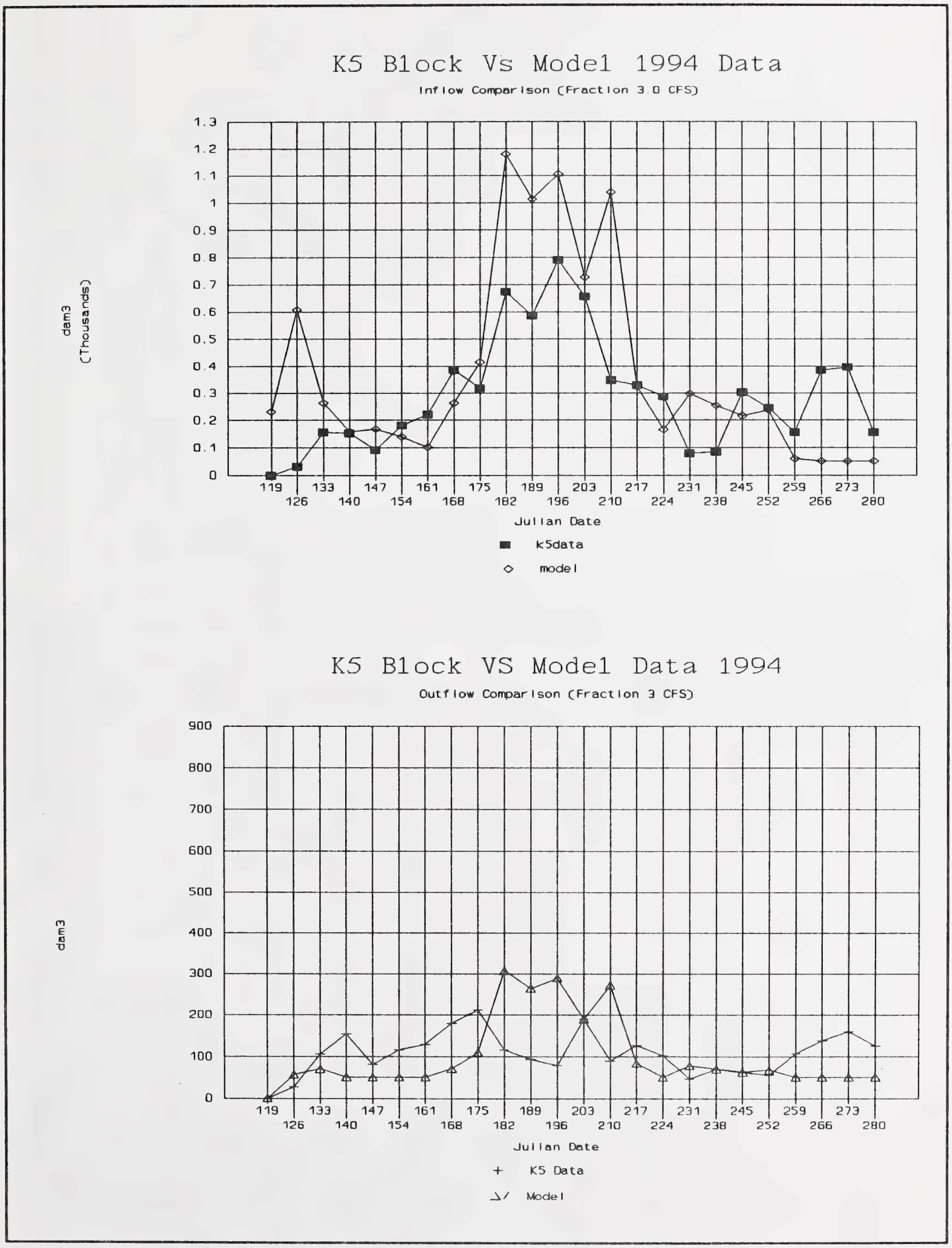

Figure 3: Fraction Method

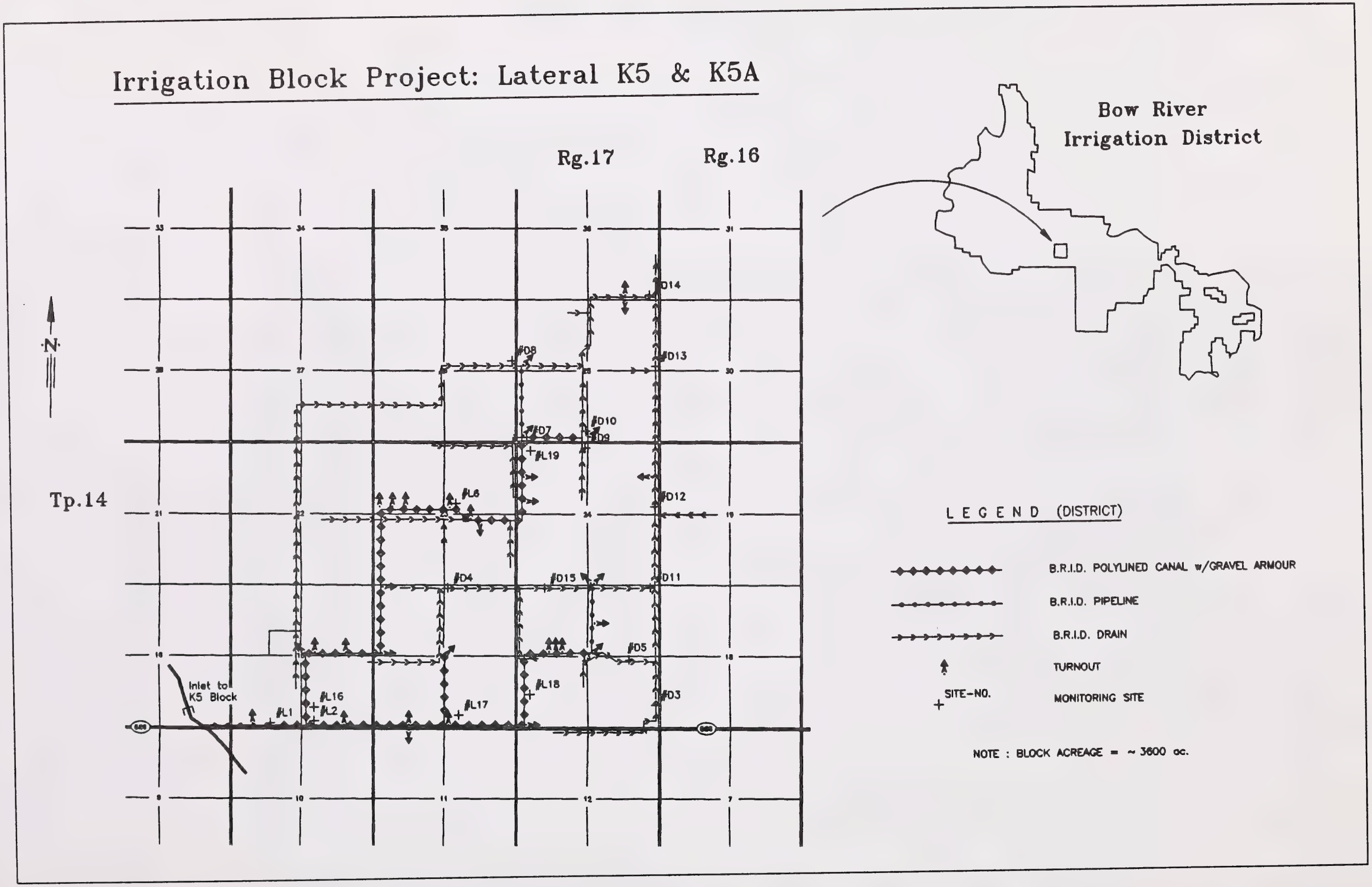

Figure 4 : Location of Stilling Wells.

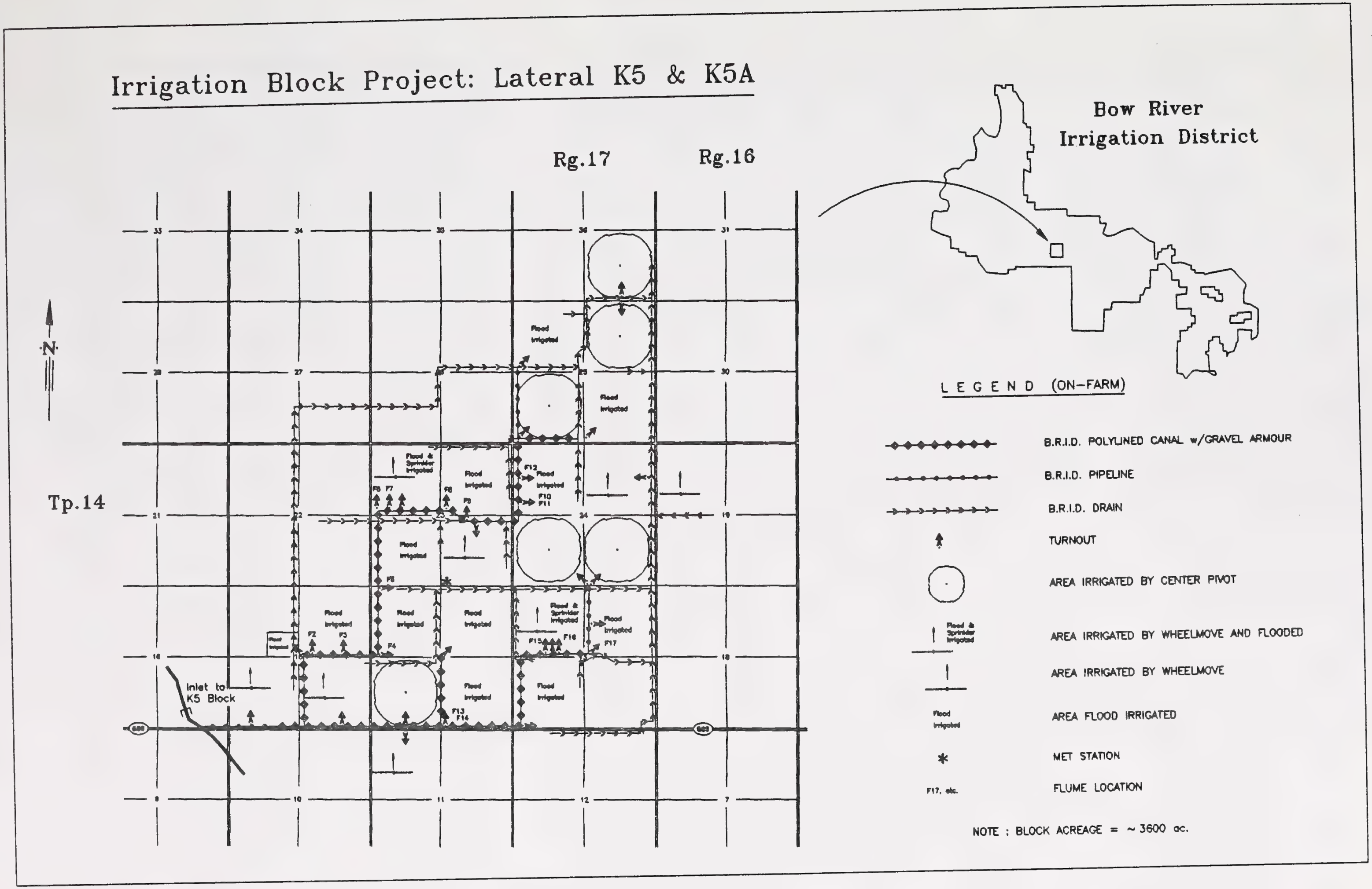

Figure 5 : On farm Cutthroat Flume Location.

FALL IRRIGATION STUDY - 1994

R. Riewe P.Ag., B. Handerek[1]

INTRODUCTION

The purpose of this report is to examine the effects of varied fall applications of water and fall cultivation practices on spring soil moisture conditions within a one metre root zone.

Previous work has shown that increased fall irrigation application amounts provided higher spring soil moisture levels but corresponding increases in irrigation water lost to evaporation and/or deep percolation for all plots located in the cultivated test section. In standing stubble, increased fall application amounts resulted in elevated spring soil moisture levels but evaporative and/or deep percolation losses were varied.

With no fall irrigation application for the 1993/94 season, the stubble treatment had an overwinter moisture gain 19% greater than the cultivated treatment. The stubble half of the site also measured higher spring soil moisture with depth.

METHOD

The time frame for the study is the overwinter period from October 1, 1993 to April 1, 1994.

The project is located in the SE¼ 2-10-21-W4, approximately 10 km north of Lethbridge. The plot design was a 2X4 factorial, with sub-treatment being replicated three times. The plots will have the following treatments:

- standing stubble and cultivated treatment
- 3 irrigation and a non-irrigation treatment

The cultivated treatment was worked once. The irrigation and non-irrigation treatments were randomly arranged in each block. The size of each plot was 6.1 m x 6.1 m (20' x 20') with a 9.15 m (30') buffer zone around each plot. The entire block was to be irrigated with a solid set irrigation system. Each sprinkler had a ball valve attached to it so each plot could be irrigated independently of each other.

The late summer and fall of 1993 was very wet, with 136 mm of rain in the two months prior to the start of the 1993/94 study period. As a consequence, no irrigation was applied for this season and the overwinter performance of the stubble and cultivated areas was compared. Entire project area was at field capacity due to this abundance of precipitation.

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Temperature, precipitation and sunshine hours information was obtained from Agriculture Canada at Lethbridge.

Prior to the study period, a 1.5 m long aluminum access tube was installed centrally in each plot. Using a Campbell Pacific neutron probe, soil moisture readings were taken at 25 cm intervals to a depth of 1.5 m. The 100-150 cm depth was monitored for possible deep percolation of soil moisture beyond the 0-100 cm zone. Soil moisture monitoring was performed on a weekly basis during late fall and early spring and as weather or field conditions permitted during winter.

RESULTS

The winter of 1993-94 was considerably warmer with less precipitation than this same time period one year ago. During the 1993/94 overwinter period, there were 146 days (77.3%) that had maximum day time temperatures greater than 0°C and 52 days (27.5%) with minimum day time temperatures greater than 0°C. There were 24 days (12.7%) that had day time temperatures greater than 15°C. During the 1992/93 over winter period, there were 114 days (63.7%) that had maximum day time temperatures greater than 0°C and 37 days (20.7%) with minimum day time temperatures greater than 0°C. There were 13 days (7.3%) that had day time temperatures greater than 15°C.

Overwinter precipitation for this time period is on average 118.9 mm. In 1993-94, the plot area received only 85.8 mm of precipitation. Climate data given in Table #1 was recorded by the Agriculture Research Centre in Lethbridge.

TABLE #1. SEASONAL CLIMATIC DATA

	MEAN TEMP (°C)		TOTAL PRECIP. (mm)		TOTAL SUNSHINE (HOURS)	
MONTH	1993/94	LONG TERM	1993/94	LONG TERM	1993/94	LONG TERM
Oct/93	7.5	7.0	16.8	22.3	195.5	171.4
Nov/93	-1.7	-0.7	14.0	18.6	121.9	114.3
Dec/93	-0.8	-5.8	9.2	18.4	83.7	94.6
Jan/94	-7.1	-8.6	26.3	18.6	63.9	98.6
Feb/94	-12.4	-6.4	18.7	17.5	124.0	124.6
Mar/94	4.1	-1.6	0.8	23.5	226.8	164.1

Table #2 describes the soil characteristics of the project area.

TABLE #2: SOIL PHYSICAL PROPERTIES

DEPTH (cm.)	BULK DENSITY (g/cm^3)	FIELD CAPACITY (mm)	PERMANENT WILTING POINT (mm)	AVAILABLE WATER (mm)
0-25	1.4	106	49	57
25-50	1.4	112	48	64
50-75	1.4	107	49	58
75-100	1.35	107	47	60
100-125	1.35	103	49	54

Due to the high level of precipitation, 378 mm June through September of which 136 mm was in August and September, soil moisture levels throughout the project area were uniformly elevated with very little differences in soil moisture. Moisture levels in the root zone were close to field capacity (Figure #1).

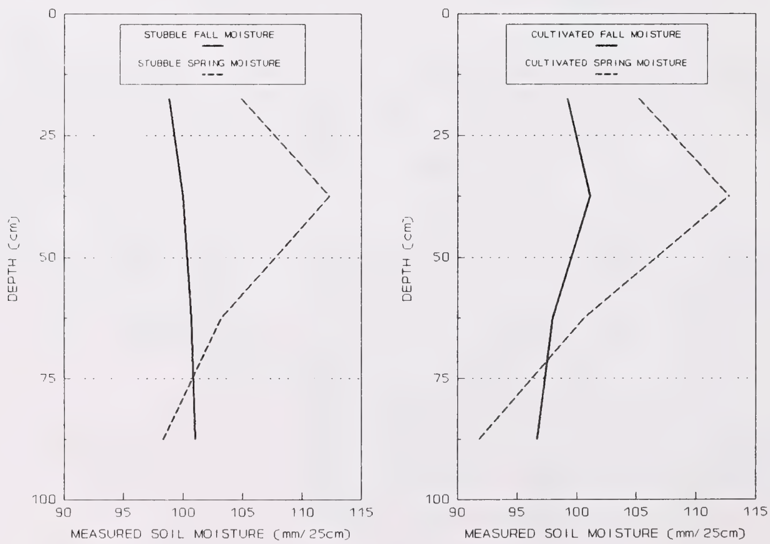

Figure 1: Stubble and Cultivated Soil Moisture Levels

Seasonal evaporative losses were largest for the cultivated treatment. The cultivated treatment had a total loss of soil moisture of 72.1 mm and the stubble treatment a total loss of 68.0 mm. The total loss of soil moisture includes 85.8 mm of overwinter precipitation.

The amount of water lost was 0.36 mm/day for the stubble treatment and 0.39 mm/day for the cultivated treatment. The amount of water lost under cultivated conditions was 8% greater than stubble.

The stubble treatment showed a gain of soil moisture with depth over the cultivated treatment (Figure #1).

Overwinter soil moisture levels increased 15.3 mm and 18.2 mm for the cultivated and stubble treatments respectively. This represented a 19% greater soil moisture increase for the stubble treatment. Neither of the treatments resulted in water movement below the 0-100 cm zone.

SUMMARY AND CONCLUSIONS

This was the third year of the study. Precipitation of 85.8 mm for the overwinter interval was well below the seasonal average of 118.9 mm. There was no irrigation on either stubble or cultivated plots with the stubble stand for 1993/94 being less substantial than that of 1992/93.

Both cultivated and stubble sites showed soil moisture increases in the spring. The 0-50 cm zone was nearly identical for both treatments with the stubble treatment having a higher soil moisture level in the 50-100 cm zone. Neither treatment lost soil moisture to deep percolation.

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DEMONSTRATION OF A MICROCOMPUTER-BASED IRRIGATION MODEL TO SCHEDULE IRRIGATIONS

Gregg Dill P.Eng.[1], Bob Riewe P.Ag.[1], Dr. Nader Foroud[2], Bryan Smith[1]

INTRODUCTION

Part of irrigation management is scheduling irrigations to ensure soil moisture is always adequate for crop growth. Agriculture and Agri-Food Canada has developed an irrigation model based on crop consumptive use and soil moisture. Dr. Nader Foroud has been involved with development of the model. The model was field tested over three seasons (1987-1989) with good results. During the 1994 irrigation season we used the model as a tool for making irrigation scheduling decisions. The model estimates daily crop water use and suggests timing and amounts for irrigation using daily weather data and soil parameters.

Project Objectives

1) To demonstrate the use of a computer model to schedule irrigations.
2) To determine if the model is user friendly.
3) To determine if the model is useful in making proper water management decisions.

METHODS

The model as received from Agriculture and Agri-Food Canada was demonstrated to the cooperating producers, Mr. Cam Campbell and Mr. Murray Lewis. The Campbell site was irrigated with a wheel move system and the Lewis site with a pivot. The initial reaction was concern over the complicated data file management required by the model.

The model was also evaluated for technical accuracy by comparing AIM (Alberta Irrigation Management Program) results with model results. The AIM data was collected over several years as part of the program to teach irrigators proper water management practices. Under the program a technician visits each irrigator once a week to teach techniques and record moisture levels and consumptive use rates. The data provided a good database for desktop comparison. Initial results were discouraging when fields were selected at random. When top producing fields were selected the results were much more encouraging.

The user interface was changed to make it more user friendly but still vulnerable to operator errors. The file management process was simplified but does

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require a knowledge of how to use a file editor to correct data entry errors. The model operates in DOS and requires a knowledge of some DOS commands.

Three crops, durum, canola and dry peas, were monitored at the Coaldale (Campbell) site and two crops, canola and soft wheat, at the Summerview (Lewis) site. Each field was instrumented with a five metre water table well, three neutron access tubes and a rain gauge. Mechanical analysis was completed on the soil cores taken when the neutron access tubes were installed. Initial and final soil moisture content was determined in the field by the AIM technician. Neutron meter and rainfall/ irrigation readings were taken weekly and each site visited weekly as a routine part of the AIM program.

Weather data from the Lethbridge Research Station was used for the Coaldale site and from a weather station at Summerview maintained by the Irrigation Branch for the Summerview site. A paper copy of the data was delivered to Mr. Campbell and manually entered into the computer for use in the model. Mr. Lewis downloaded the weather data weekly from a computer in the Lethbridge Irrigation Specialist's office. The model was run weekly by the cooperator and discussed during the AIM technician's weekly visit.

RESULTS

The two producers used the model during the 1994 irrigation season to determine: 1) if the model is user friendly; and, 2) if it is useful in making water management decisions. Comments from the producers are the best measure of determining the results of these objectives.

Comments

The model was considered user friendly by both cooperators and predicted irrigations accurately (within 2-3 days).

Recommendations were made on how to improve the format of the output data. Some of these recommendations were implemented during the project and others will be included in the next revision. Recommendations include: 1) allow editing "Soil Moisture Depletion", 2) use Calendar Day instead of Julian Day for input and output, and 3) separate irrigations from rainfall in output report.

The model confirmed the need to irrigate within two to three days of the AIM Technician recommendation. This is well within the accuracy required for good irrigation management considering the range of conditions that exist in a field.

Although the cooperators developed confidence in the model they suggest it should not be used as the only decision making tool. It is still essential that periodic field verification be done to confirm predicted soil moisture levels.

The cooperators found the model reasonably easy to use and plan to use it during the next irrigation season with minimal support from the AIM technician. One of the producers had very limited exposure to computers but considered the model results valuable enough to learn DOS and DOS Editor operations! The other cooperator was a new irrigator and found the model useful as a tool for learning crop consumptive use patterns. He took the output data and produced graphs to analyze

the results and identify trends.

Results at the Summerview site were compromised due to the lack of data from the local weather station. Approximately 40 per cent of the data was actually Lethbridge Research Station data except for rainfall which was collected locally. The Lakewood datalogger used was not designed to operate in this application and consequently failed almost every week of the irrigation season. The datalogger could not accept data as fast as it was sent from the anemometer and other transducers at the same time. Lethbridge data was also undependable for periods during the irrigation season but was eventually available, unfortunately, after assumed data had been used to run the model.

An example of the weekly LRSIMM report and IRRIGATION report are shown in Table 1 and Table 2. These reports are produced for each field identified when the model is first run. A field may be a different crop, a different soil type, different moisture conditions or different irrigation management.

Table 1. Weekly Weather and Crop Use Report

LRSIMM REPORT for: DL Campbell & Sons Ltd. to Jun 23

FIELD 3: PEAS REGION: Lethbridge BEGINNING DATE: May 1

JULIAN DAY (no.)	CALENDAR DATE	MAX TEMP (C)	MIN TEMP (C)	SOLAR RADIATION (kj/m2)	WIND (km/day)	RAIN and IRRIGATION (mm)	CROP USE (mm)
168	Jun 17	20.0	4.2	30101	234	0.0	4.1
169	Jun 18	22.8	4.0	25347	234	9.0	3.5
170	Jun 19	21.7	3.8	32192	427	0.0	5.7
171	Jun 20	25.8	4.5	30180	197	0.0	5.0
172	Jun 21	25.0	10.8	31190	240	53.0	5.5
173	Jun 22	28.4	9.8	27940	196	0.0	5.8
174	Jun 23	29.1	14.6	26497	291	0.0	6.2
				Weekly Totals		62.0	35.7
				Season Totals		153.0	153.3

Table 2. Weekly Irrigation Report

IRRIGATION REPORT for: DL Campbell & Sons Ltd.

CROP or FIELD	REPORT DATE	SOIL MOISTURE DEPLETION TO-DATE (mm)	ALLOWABLE (mm)	REMAIN (mm)	IRRIGATIONS LAST	NEXT	AMOUNT (mm)
PEAS	Jun 23	65	96	31	Jun 21	Jun 30	96

The LRSIMM report (Table 1) includes the input weather data which can be checked for errors and corrected as required. Crop Use is calculated using a modified Jensen-Haise equation and crop coefficients which have been extensively tested in southern Alberta. Weekly and season totals for rain and irrigation as well as crop use are included to provide an overview of the moisture - crop use relationship.

The IRRIGATION report (Table 2) provides the soil moisture depletion situation to date and recommends the date of the next irrigation based on standard crop use

curves. In Table 2 the 'soil moisture depletion to date' of 65 mm appears high since the field was irrigated on June 21. A depletion of 100 mm on June 21 was reduced to 47 mm after the 53 mm irrigation but consumptive use increased the depletion to 65 mm by June 23. The irrigation was not enough to bring the field up to field capacity. The recommended amount of the irrigation is based on the allowable soil moisture depletion provided as input during model initialization.

LRSIMM results, AIM estimates and neutron probe readings are compared in Figures 1-5. For all fields except Lewis canola (Figure 1) the model predicted higher consumptive use later in the season and consequently, predicted irrigations that were considered unnecessary by the AIM technician and the neutron probe. This divergence often occurred after the irrigation season was over. In the soft wheat field (Figure 2) consumptive use estimates seem to be slightly higher than field measurements. The model consistently estimates consumptive use about 0.3 mm higher throughout the growing season. A higher yielding crop may be predicted closer to field measurements. The Campbell peas field (Figure 5) dropped below 50 per cent available moisture in July due to system limitations. The Campbell canola field (Figure 3) was in a high water table area which the model was not able to account for although there are provisions for it in the future.

Figure 1.

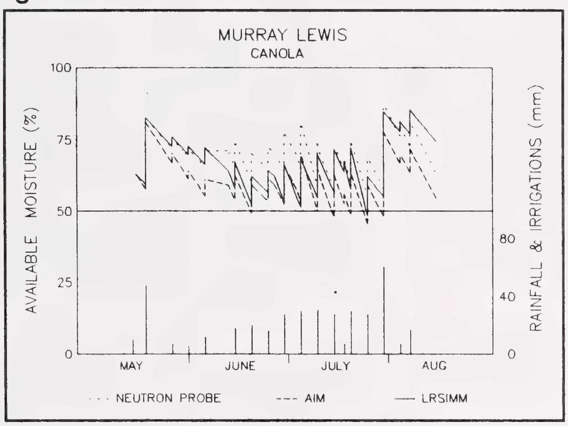


Figure 2.

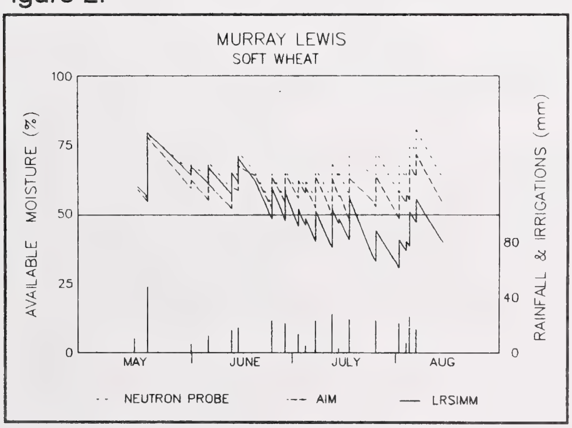


Figure 3.

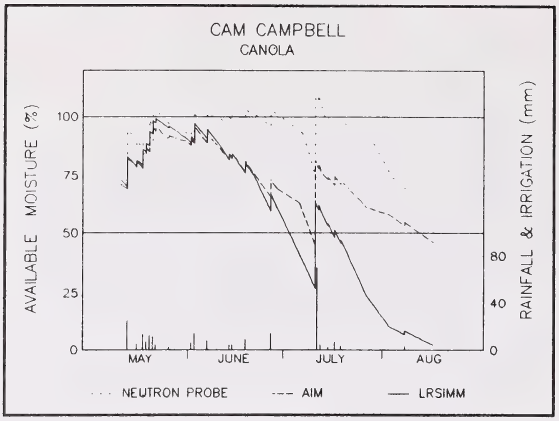


Figure 4.

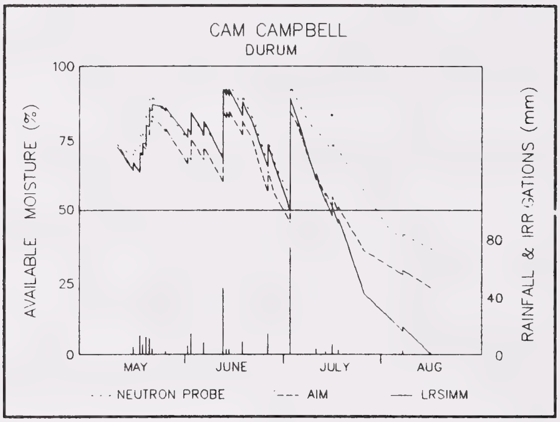
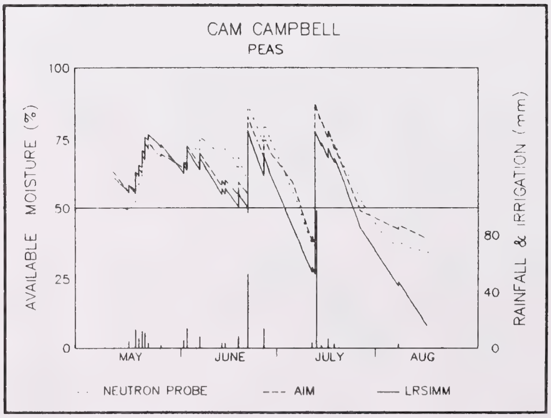


Figure 5.



DISCUSSION

The model predicted irrigations and provided water management information for the crops selected accurately and well within the range required to be a useful tool. Some concerns were identified which need to be addressed in the future:

1) Inconsistent availability of weather data had a major affect on the ability of the model to predict irrigations. If the model is to be used in Southern Alberta it is essential the information be available at enough locations to estimate solar radiation and wind run. Rainfall, maximum and minimum temperatures should be recorded locally.

2) It does not calculate alfalfa consumptive use accurately after the first cut. When information is available an adjustment accounting for cutting should be incorporated in the model.

3) It is most successful at predicting irrigations for top producing fields. A management factor could be incorporated or the poor results could point to suggesting that agronomic practices could be changed to improve production. Model predictions should then be more representative.

4) The model requires available water holding capacity and initial soil moisture depletion as input for the initialization run. Both can be estimated by the hand method or determined by laboratory procedures. Few producers understand these concepts and would need support in the initialization stage.

5) The model over predicts the crop use near the end of the growing season for most of the fields monitored. Adjustments to the harvest date did not have any effect on the crop use.

CONCLUSION

The model was successful in predicting irrigations for the crops monitored during the 1994 irrigation season. It is a useful tool but does not replace manually monitoring the fields using the techniques taught through the AIM program. The model should be tested at different locations in Southern Alberta to determine the area it can predict successfully. Further development is required to address the short comings discussed above.

Thanks to AARI (OFD) program for their support to the project and Dr. Sean McGinn of Agriculture and Agri-Food Canada for making weather data available from the Lethbridge Research Station. Thanks also to staff who supported the project in various ways from establishing monitoring sites to collecting data.

A COMPARISON OF SURGE FLOOD IRRIGATION TO CONVENTIONAL FLOOD IRRIGATION ON BORDER DIKED FIELDS 1994

G.A. Snaith and J.M. Bakker[1]

INTRODUCTION

This second year of a two year study used surge flood irrigation on two southern Alberta fields developed on a fine textured lacustrine soil. The objective of this project was to demonstrate to surface irrigators and irrigation districts that there is an opportunity to utilize the surge flood concept to increase on-farm water management control for border dike irrigation. Conventional flood irrigation allows the water to continuously flow until the water front reaches the end of the border block. With surge flood, the border block is irrigated in cycles to capitalize on lower soil infiltration rates upon subsequent cycles. The site is located at Tilley, Alberta (S1/2 30-16-13 W4). The study included one field 354 meter in length and one field 777 meter in length. These two fields approximate typical 1/4 mile and 1/2 mile irrigation schemes. In each case surge flood irrigation is compared to conventional flood for water advance times and amount of water applied.

METHODS

For field identification, the two fields were labelled Field A and Field B and demonstrated closed and open water conveyance systems. Field A represents a 1/4 mile long alfalfa hay field serviced by flexible gated pipe. Field B represents a 1/2 mile long soft wheat field serviced by a permanent grassed head ditch.

The fields were set up to compare surge flood to conventional flood irrigation by monitoring the advance times and water applied. In 1993 the total time of each cycle was recorded, but in 1994 individual advance times within each cycle were also recorded. For more details of equipment and measurement procedure refer to the Division's 1993 report (Snaith 1993). Each field included two conventional flood irrigation blocks as a control measure with the remaining blocks used for surge flood irrigation trials. On-off cycle times for surge flood border blocks were based on the advancement of the wetting front. Soil infiltration rates were collected and weekly soil moisture data was provided to the producer to assist with irrigation management.

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Field A

Field A is a seventeen hectare border diked alfalfa hay field of predominantly clay loam soil texture. The border blocks have a 0.3% downfield slope, are 19 meters wide, and average 354 meters in length. The study area consisted of ten border blocks, five on each side of an irrigation district delivery turnout.

Flexible gated pipe was connected to a tee junction and delivered water east and west from the delivery point. Eighteen gates were installed in the pipe for each border block. Field A layout is illustrated in Figure 1.

Irrigation events were June 11-13 and July 25-29. Blocks R3 and L3 were used as control blocks representing conventional flood. The remaining eight borders were used for surge flood trials. Surge flood pairs were: R1/R2, R4/R5, L1/L2, and L4/L5. The study area was separated into the left and right group of five border blocks on each side of the turnout.

During the first irrigation the cooperating farmer wanted to minimize the application depth by shutting the water off before the water front reached the end of the field. Therefore, two cycles were monitored using the 1/3 and 2/3 distance of the field as set points for determining cycle times. During the second irrigation, two surge cycles were again used but with advance distances of 1/2 and full length of field.

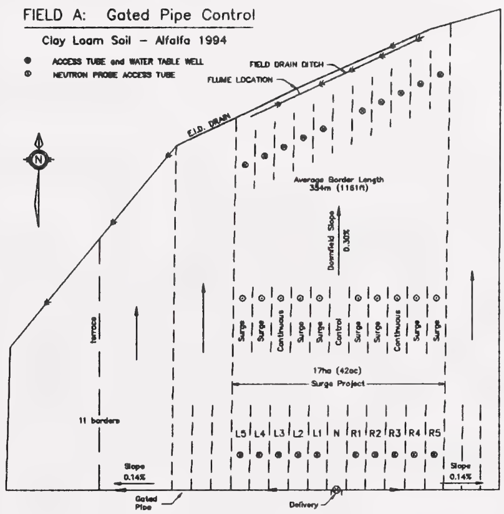

Figure 1. - Field A Layout

Field B

Field B is an eight hectare soft wheat field with 4 border blocks. In 1994 two soft wheat varieties were grown. AC Reed was grown on blocks B1 and B2, and Fielder on blocks B3 and B4. The soils are predominantly a clay loam to a sandy clay loam texture. The border blocks have a 0.45% downfield slope, are 19 meters wide, and average 777 meters in length.

Water delivery is via a permanent grassed head ditch with four 203 mm diameter PVC pipe turnouts for each border block. Field B layout is illustrated in Figure 2.

Irrigations events were July 5,6 and July 30,31. B1 and B3 were used as the conventional control blocks while B2 and B4 were used as a surge flood pair. For both irrigations, 3 cycles were used with the 1/3, 2/3 and the end of the field as set points for determining cycle times. For both the conventional and surge applications, the water was shut off to each block when the wetting fronts reached the end of the field.

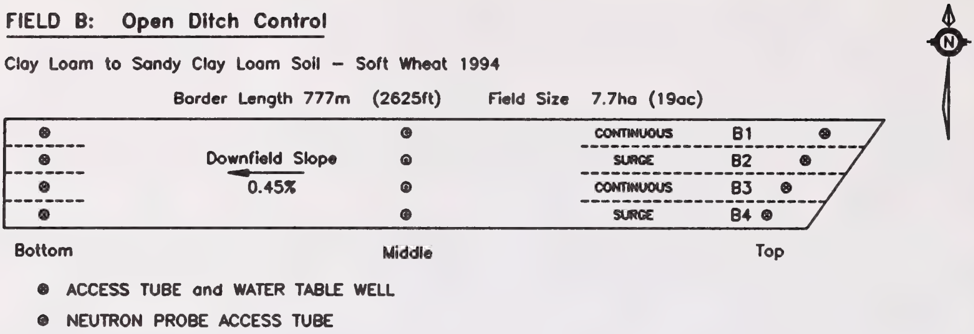

Figure 2. - Field B Layout

RESULTS AND DISCUSSION

Field A

Soil Infiltration Tests

Infiltration tests were conducted prior to each irrigation. For the first irrigation, an infiltration rate of 12 mm/hr (0.47 in/hr) was recorded after two hours. For the second irrigation, an infiltration rate of 24 mm/hr (0.94 in/hr) was recorded after two hours. This significant difference between the two rates can perhaps be attributed to either a confined change in soil texture for the second testing site or macro soil surface cracking prior to second irrigation.

Flow Rates

Monitoring water flow rates resulted in the following information:

[1] 18 Gates per Block [2] 4 Pipes per Block		FIELD A		FIELD B	
		1st Irrigation June 11-13	2nd Irrigation July 25-29	1st Irrigation June 5-6	2nd Irrigation July 30-31
FLOW RATE	Border Block	98 L/s (1550 GPM)	101 L/s (1600 GPM)	122 L/s (1930 GPM)	95 L/s (1500 GPM)
	Per Gate [1]	5.4 L/s (86 GPM)	5.6 L/s (89 GPM)		
	Per Pipe [2]			30.5 L/s (482 GPM)	23.8 L/s (375 GPM)
WATER APPLIED	Continuous	169 mm	295 mm	158 mm	NO DATA
	Surge Cycles	168 mm	280 mm	148 mm	118 mm

Table 1. - Average Flow Rates

Advance Times

For the first irrigation, two surge cycles were used and advance times were based on the water front reaching the 1/3 and 2/3 distance. Except for R4, the right blocks indicate advance time savings of 8% to 12% for surge flood compared to control block R3. Advance times for Field A are indicated in Figure 3. Examining the left blocks also indicate advance

time savings utilizing surge flood, although the initial 1/3 advance time for the control block L3 was greater than compared to the remaining blocks, except for L1.

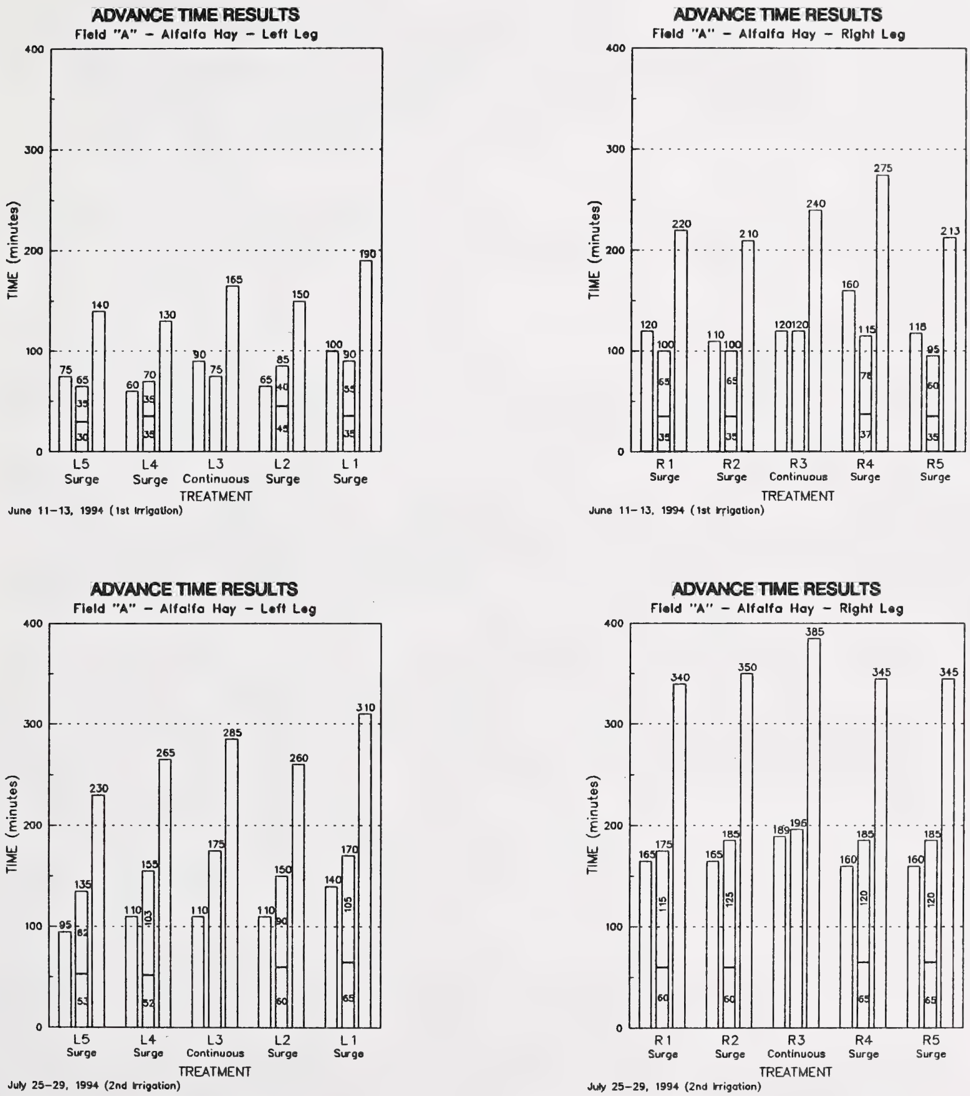

Figure 3. Field A Advance Times

Two surge cycles were also conducted for the second irrigation but with advance distances of 1/2 and full length of field. All surge blocks to the right saved time but the advance time for the first 1/3 distance was significantly greater for control block R3. For the

left block, except for L1, all surge blocks saved advance times as compared to the control block L3.

Soil Moisture

All water application treatments nearly achieved field capacity. However, the surge flood blocks did show increased application uniformity by having a more uniform available moisture profile from the top to the bottom of the field. Water table well monitoring indicated a dramatic rise in the water table following each irrigation indicating deep percolation.

Yield

Yield results indicate no significant difference between treatments. The first cut of alfalfa averaged a field weight yield of 1.0 tonnes/ha (2.5 tonnes/acre).

<u>Field B</u>

Soil Infiltration Tests

Two infiltration tests were conducted, the first at the beginning of the season and the second prior to the first irrigation. A first rate of 12 mm/hr (0.47 in/hr) and a second rate of 10 mm/hr (0.41 in/hr) was recorded within two hours.

Advance Times

Results indicate time savings and improved application uniformity under surge flood conditions. Three surge cycles were conducted on Field B for both first and second irrigations. For the first irrigation, B1 and B2 can be used as a comparison of surge to conventional, indicating advance time savings of 6%. B3 and B4 were irrigated during the night and only partial data was collected on B4.

For the second irrigation, advance times for B2 and B3 were obtained only. No comparison can be made to a conventional block but as seen in figure 4, the repeat of second and third advances indicate a significant reduction in advance times supporting the sealing off effect of the soil upon subsequent applications.

Soil Moisture

The top of all blocks were filled to field capacity. The difference between the surge blocks and the conventional blocks became apparent in the application uniformity. There was less difference in top to bottom moisture percentage for the surge blocks versus the conventional blocks.

Yield

There were no significant differences in average yields among the four blocks. The average yields ranged from 6.0 tonnes/ha (88.5 bu/Ac) to 6.3 tonnes/ha (93.5 bu/Ac).
There was a trend for the yield to decrease and protein to increase from top to bottom of the blocks. The highest yield was at the top of B2 with 103.1 bu/Ac while the lowest yield was at the bottom of B3 with 76.7 bu/Ac.

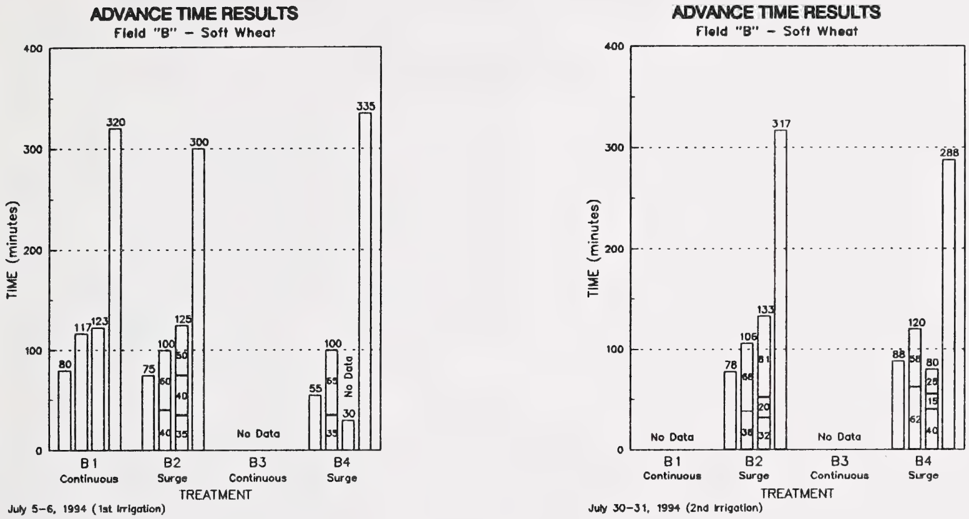

Figure 4. Field B Advance Times

CONCLUSIONS

Much of the research for surge flood irrigation has been done on furrows with a moderate examination of the response of surge flood on border dike fields. This project has been conducted on clay loam soils at Tilley, Alberta. Like 1993, 1994 results also indicate noticeable savings in water advance times and improved application uniformity under surge flood irrigation conditions compared to conventional flood of continuous flow. For 1993, up to 17% savings in advance times have been achieved utilizing surge flood. In 1994 a maximum of 19% savings in advance times was noted.

Because of the large water front associated with border dike irrigation, on average water application amounts were great enough to fill the root zone to field capacity. In this particular study, surge flood irrigation on border blocks did not significantly reduce the amount of water application. However, surge flood can be viewed as an opportunity to increase on-farm water management control by reducing advance times, reducing tailwater and increasing water application uniformity.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of the cooperating producers, Edwin and Josephine Bronsch, Farming for the Future, the Alberta Soft Wheat Producers Commission, and the members of the project's Technical Advisory Committee.

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EVALUATION OF SPRING BACKFLOOD IRRIGATION IN CENTRAL ALBERTA

N.D. MacAlpine, J.E. Prochnau, R.M. Ackroyd and E. Bittner[1]

INTRODUCTION

Spring backflood irrigation is early spring flood irrigation. Water from snowmelt is diverted from creeks or ditches and flooded onto frozen soils. As the soils thaw under the flooded water, the water infiltrates and recharges the root zone soils with moisture. In the Canadian prairies, snowmelt is usually the only runoff event in the year. Where soil moisture limits crop production, snowmelt is the single opportunity to capture excess water and store it in the soil profile. This technique has been used for many years in southern Alberta. However, in central and northern Alberta, snowmelt has generally been considered as excess water, a nuisance to get rid of as quickly as possible.

However, even in these areas of higher moisture, forage and grain crops often suffer from drought stress later in the summer when root zone soil moisture is used up. Also as farmers improve their field drainage to speed up snowmelt removal for earlier spring operations, off-farm drainage systems come under pressure to move large volumes and erosive rates of runoff from snowmelt. Upgrading these systems results in high capital costs.

Both factors justified a demonstration of the on-farm benefits of managing snowmelt to improve forage yields and the off-farm benefits of reduced flood peak flow rates and erosion protection. The Golden Glow Spring Backflood Irrigation Demonstration near Millet in the County of Leduc was completed in 1989 and monitored for four years. The cooperation of Gerald and Marvin Pohl and Steve Moen, the farm managers, and the County of Leduc was very valuable in the development and monitoring of this project.

The key objectives of the study were;

- To demonstrate soil moisture conservation and good water management practices with spring snowmelt.
- To investigate the spring flooding tolerance of various forages.
- To investigate soil warming in spring backflooded areas.
- To demonstrate the downstream benefits from controlled drainage.
- To illustrate the economic benefits of controlled drainage.
- To illustrate the environmental benefits of controlled drainage.

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METHODS

In the fall of 1988,the outlet watercourse was deepened and the field ditch down the centre of the 22 hectare wet meadow basin was partially excavated (Figure 1). The control structure was installed in 1989 and the outlet watercourse's sideslopes were reshaped. The field ditch through the backflood irrigation area was deepened in 1990, to help dewater the surrounding muck soils.

Forage plots of two legumes and four grasses, each replicated three times were established in the summer of 1990 in the backflood area and an unflooded upland area. The plots consisted of Peace alfalfa, alsike clover, reed canary grass, Carlton bromegrass, creeping foxtail and Climax timothy. Plot yields and forage quality were measured in 1991 and 1992. New varieties were seeded in 1992 for future monitoring. The new varieties were seeded in the 1990 plots, and replicated either 2 or 3 times in both the backflood and upland plots. The new forage plots were tall fescue, tall wheatgrass, western wheatgrass, Climax timothy and Magna bromegrass.

A climate station was equipped for automatic data recording of daily temperatures, relative humidity, rainfall including intensity and duration. Thermocouples were installed to help monitor soil temperatures and frost recession. Four thermocouple nests were placed in the upland and backflood plots respectively. Each nest had a thermocouple at depths of 5, 10, 20, 40, 60, 80, and 100 cm. Frost recession was measured by probing down to the frost layer. Runoff measurements primarily at snowmelt, required frequent visits to record flood levels, flood duration, soil temperatures, and frost recession. Detailed mapping of the backflooded area was necessary for determining the volume of runoff and for comparison with regional data. The downstream drainage channel was surveyed for modelling the flood routing of snowmelt. Soil moisture levels were recorded by taking soil samples and also with a neutron probe. During spring runoff, observations and photos were taken of wild waterfowl staging on the backflooded area. Downstream flowrates and impacts were also monitored prior to construction in 1989 and after construction from 1990 to 1992.

A hydrology software model OTTHYMO, (Wisner et al, 1989), was used to predict peak flowrates and high water levels in the water course beside the two downstream acreages. Runoff flows under natural (snow dam break) conditions and controlled outflows from spring backflooding were modelled using OTTHYMO (Ackroyd et al, 1993). The model was calibrated with runoff volumes and runoff rates measured in 1989 to 1991.

Ackroyd et al (1993) completed a detailed farm financial analysis and socio-economic analysis. The farm financial analysis looked only at on-farm costs and benefits while the socio-economic (public) analysis also included off-farm development costs and associated benefits.

The backflood area was successfully cropped in 1992 with a canola crop underseeded to a mixture of bromegrass, meadow foxtail and timothy. In 1993, two cuts of grass hay were harvested from the backflood area. Part of the backflood area was reseeded where seeding in 1992 was missed. The newly established plots in 1992 were monitored to determine the forages' flood tolerances.

RESULTS

Flood Protection Costs with Backflood Irrigation

Table 1 summarizes the construction and development costs of the project at custom rates. The farmer cooperators built and seeded the project for less since they used their own equipment for some work. Engineering design was at no cost from Alberta Agriculture, Food and Rural Development.

Table 1: On-Farm Construction and Development Costs

Construction Items	Costs	Forage Development	Costs
Engineering Design	$1,263.30	Breaking	$2,113.73
Channels Improvement	15,307.00	Weed Control Cultivation	2,586.12
Control Structure	3900.00	Forage Seed & Seeding	1,106.10
Channel Seeding	737.00	Maintenance (2 years)*	848.30
Total Construction Costs	**$21,207.30**	**Total Development Costs**	**$6,654.25**

* Maintenance costs estimated as 2% of project's capital costs.

To compare the downstream benefits of controlled flows versus uncontrolled drainage, the hydrology of the project before and after installation of the control structure was monitored. Monitoring in 1989, before the control structure was built, showed that snow dams in the outlet watercourse normally would flood upstream snowmelt over the 22 hectares of wet meadow. When the snow dams broke, the 22 hectares of flooding drained in a matter of hours. Two houses on acreages next to the downstream watercourse were nearly flooded. An oversized road culvert, 1.8 metres in diameter, immediately upstream of the acreages, was evidence that snow dam break events were a regular occurrence. The high water marks from this event plus detailed estimates of the runoff volume were used to calibrate OTTHYMO (Wisner et al 1989). OTTHYMO is a hydrology model that also has a routing function. Downstream channel cross sections were surveyed for use in the model. Controlled drainage events from 1990 onwards were also monitored for high water marks and volumes to check OTTHYMO's predictions.

Table 2: Runoff Depths and Unit Area Peak Flowrates from Golden Glow

Year	Runoff Depth mm	Return Period	Peak Flowrate m^3/s per km^2	Return Period
1989	9.8	1:2	0.620	> 1:100
1990	22.2	1:4	0.074	1:4
1991	11.7	1:2	0.037	1:2
1992	11.5	1:2	0.037	1:2

Return Periods were estimated from long term flow records from Pipestone Creek, near Millet. The 1989 monitoring illustrates the effect of snow dam breaks; a normal snowmelt volume produces a 1:100 year peak flowrate when the snow dams break. The operation of the control structure significantly reduced peak flowrates from 1990 onwards.

OTTHYMO was used to predict peak flowrates and high water levels for uncontrolled snow dam break events and controlled drainage releases from spring backflood irrigation for a variety of normal and extreme events. Once OTTHYMO was calibrated to predict high water levels equivalent to observed events, the downstream watercourse cross sections were varied to predict the level of construction required to contain flows within the channel's banks for both the uncontrolled drainage scenario and the spring backflood irrigation's controlled releases.

OTTHYMO's predictions were confirmed when the County of Leduc completed downstream improvements equivalent to OTTHYMO's predicted earthwork volumes for the controlled flow scenario. OTTHYMO also predicted that a snow break event for a snowmelt volume larger than a 1:5 year return period would flood at least one of the downstream acreage houses. Although 1990 had a snowmelt volume close to a 1:5 year return period, the backflood irrigation control structure released runoff slowly enough that downstream homes were not at risk.

Table 2 summarizes the actual and predicted construction costs for the two water management scenarios: controlled flows from spring backflood irrigation and uncontrolled flows from a natural snow dam break event.

Table 3: Total On-Farm and Downstream Construction Costs

Controlled Drainage Option	Costs	Uncontrolled Drainage Option	Costs
On-Farm with Controls	$21,207	Uncontrolled On-Farm	$17,307
Actual Downstream Ditching	3,360	Estimated Downstream Ditches	21,280
Total for Controlled Flow	**$24,567**	**Total for Uncontrolled Flow**	**$38,537**

Flood Protection Benefits with Backflood Irrigation

The downstream acreages had been developed during the runoff droughts of the 1980's. The 1989 snow dam break event proved that those homes faced high risks from flooding as snowmelt returned to normal levels. The County of Leduc and the acreage owners had two options to deal with flood risks in the vicinity of the houses. The acreage owners could pay for flooding damage when it happened. Or the County could improve the channel through the acreages to prevent flooding. The third option, upstream control to reduce peak flowrates, is the downstream benefit of the spring backflood irrigation demonstration. Table 3 illustrates that the Golden Glow project saved County of Leduc taxpayers a total of $13,970 for an expenditure of $3,900 on a backflood control structure. The acreage owners benefitted directly from the reduced risk of flooding. Meydew (1991) estimated that cleaning and drying a flooded finished basement would be $3,000 to $5,000 not including replacement of carpets, underlay, drywall or insulation. Replacement costs of these items would average between $15,000 to $20,000. "Contents" would be in

addition to these amounts. Assuming that each flood event costs $4000 for cleanup, a house with a 30 year lifespan and a likelihood of flooding for a snowmelt volume greater than 1:5 years could have six floods at a net present cost of $15,921.16 in 1990 dollars. Avoiding these costs becomes a benefit in the financial analysis of the spring backflood irrigation project.

Agricultural Costs

Annual costs on the 22 hectares of forages were estimated as $850 for fertilizer, $2,850 for harvesting hay and $425 for maintenance of the project for an annual cost of $4,124.32. The establishment year for forages had an estimated cost of $6,194, because of higher projected fertilizer use in the establishment year.

Agricultural Benefits

Until the wet meadow was drained as part of the spring backflood irrigation development, the lowland basin had no agricultural production. Consequently, this project has agricultural benefits due to 22 hectares of new land in addition to benefits that could be attributed to better soil moisture. Forage plots were established in both upland unflooded areas and in the backflood irrigated lowland. Comparison between the two sets of plots is limited because the upland plot was sandy loam and the backflood plot was deep, well decomposed peat. However, the backflood plots indicated that creeping foxtail or reed canary grass would produce 7.8 tonnes/hectare (3.5 tons/acre) annually on the 22 hectares.

Flooding Tolerance of Forages

Flooding tolerance of various upland and lowland forages were tested in two sequences in the backflood plots. Creeping foxtail and reed canary grass performed the best in the 1990 plots since they competed strongly with other grasses. The native sedges and grasses germinated from the seed bank in the backflood area's soils and competed vigorously with any forage that did poorly in the establishment year. Bromegrass out-performed timothy in early growth after the spring flood irrigation was removed. Only creeping foxtail showed more early growth, ready for a first cut by the end of May. Neither alsike clover or alfalfa survived flooding in the 1990 plot although a 1992 seeding of alfalfa partially survived. New plots in 1992 showed that tall fescue did poorly while tall wheatgrass and western wheatgrass were less tolerant to flooding than Magna bromegrass and Climax timothy.

Based on the plot results, Gerald and Marvin Pohl seeded the backflood area to a mixture of Carlton bromegrass (12.5%), Timfor timothy (12.5%) and meadow foxtail (75%) in 1992.

Soil Thawing Under Snowmelt Flooding

Soil temperatures and frost depths were measured in both the upland and backflood forage plots in 1991 and 1992 (Prochnau et al 1993). In 1991, the upland plots thawed first. In 1992, the backflood plots initially thawed faster, then at the same rate as the upland plots. Fall soil moisture is suspected as controlling the infiltration and thawing under backflood irrigation. In 1990, the backflood plots had been summerfallowed and the lowland area was still dewatering.

Fall soil moisture in the backflood were high and thick ice lens formed during a cold, open winter. Even after a 23 day flood in 1991, thawing in the backflood soils was limited to a depth of 20 cm. In the upland sandy loams, fall soil moisture were low and soil thawing was rapid. In 1992, the backflood plots had grown one crop of forage and 1991 fall soil moisture were lower. Likewise, fall soil moisture were higher in the upland plots. In 1992, the backflood plots initially had a shallower frost lens than the upland plots. Under flooding, the backflood plots thawed quicker than the upland plots and soil temperatures at 5 and 20 cm were marginally warmer than the upland plots. Once the flood was removed, both plots had equivalent frost recession rates and depths.

Wildlife Impacts

Wildlife use of the backflood area has been affected since the backflood area had no agricultural use before the project. However, the spring staging value for waterfowl has been retained with the spring flood. As one of the earliest open water areas in the County of Leduc, numerous geese, swans and ducks rest on the backflood in the early spring.

Benefit/Cost Analysis

The economic analysis (Ackroyd et al 1993) used discounted cash flow analysis. The benefits and costs were calculated from two perspectives:
a. a farm financial analysis looking at only on-farm costs and benefits
b. a socio-economic (public) analysis for both on-farm and off-farm costs and benefits.

The socio-economic analysis considered two scenarios for the flooding risk at the downstream houses. One scenario was that the downstream landowners received benefits by not having to pay for flood damages with the backflood control structure up-stream. The second scenario was that the County of Leduc received benefits by not having to improve the downstream channels substantially.

Sensitivity analysis was done by assuming different yield levels for the backflooded forages. Ackroyd et al assumed (1993) a forage yield of 7.8 tonnes/hectare, 1990 prices ($44/tonne) for the project's lifetime, 20 years for the on-farm analysis and 30 years for the socio-economic analysis. Discount rates were 5% for the on-farm analysis and 3% for the socio-economic analysis. Benefit costs were calculated as:

1. On-farm: Net Present Production Values divided by total on-farm construction and development costs.

2. Socio-Economic: Net Present Production Values plus costs avoided by having backflood control structure operating divided by on-farm and off-farm construction and development costs.

Table 4: Benefit Cost Analysis

Forage Yield	Farm B/C Ratios	Socio-Economic B/C Ratios Benefits of Not Paying Flood Damages	Socio-Economic B/C Ratios Benefits of Not Improving Downstream Channels
Base Case 7.8 t/ha	1.6	3.1	3.3
- 20% 6.2 t/ha	0.9	2.3	2.5
+ 20% 9.4 t/ha	2.1	3.9	4.1

The B/C analysis demonstrates how significant forage yields are in determining the economics of this project.

CONCLUSIONS

The demonstration is economically viable under all scenarios except where forage yields in the backflood area are projected to be 20% less than yields measured in the backflood plots. The on-farm benefits of this project should be extrapolated with caution to other projects. There was no agricultural use of the 22 hectares now under forage production before the project was initiated. Consequently, the benefit/costs of a project where new land is developed will be significantly different for land where some agricultural production already is on-going.

Snow damming of watercourses, road ditches and culverts causes significant localized flooding of public and private property even with normal snowmelt volumes and conditions. Spring backflooding and controlled drainage offer significant off-farm benefits at the cost of reasonably priced control structures on-farm.

Creeping foxtail and reed canary grass are vigorous and productive forages well suited to backflood irrigation. Bromegrass also has strong early growth after the flood has been removed. However, replacing native grasses and sedges by tame forages requires careful consideration whether production objectives can be better achieved by working with the existing natural grasses. If tame forages are the choice, the selection of competitive species, good elimination of the native species at the time of establishment, and good germination of the tame species to establish a competitive cover are all required to successfully establish a tame forage. Otherwise the seed bank of the native grasses and sedges will reestablish native species. Flood tolerant grasses like reed canary grass and creeping foxtail gave the best competition to native grasses and yielded the best under backflood conditions.

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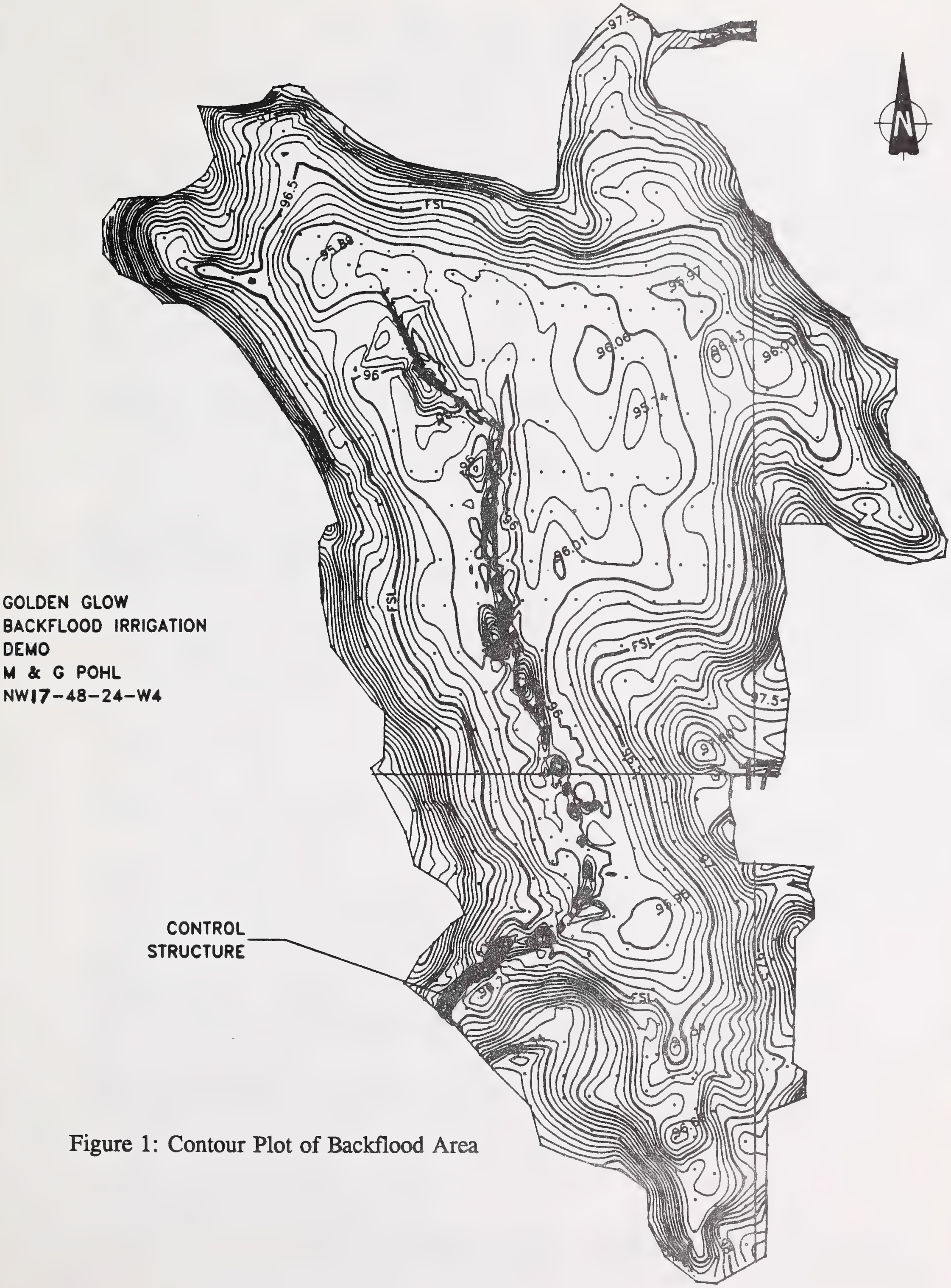

Figure 1: Contour Plot of Backflood Area

TRIPLOID GRASS CARP CANAL STUDY PHASE 11 (1994)

S. Jonas, D. Lloyd, and J. Stewart[1]

INTRODUCTION

The objective of the canal study is to test the weed control efficacy of sterile triploid Grass Carp (Ctenopharyngodon idella) in extended canal reaches similar to what might occur in an applied situation. This report presents the preliminary findings of the first year of a three-year study.

METHODS

Two research canals (O5C and J) were selected within the Eastern Irrigation District (EID). Each canal was separated from upstream and downstream control reaches by iron screen fish barriers installed at either end of the experimental section. Fish barriers were also placed on any turnout structures located within the experimental section.

The experimental area within Canal O5C is 2.5 km long and was stocked at a rate of 102 kg/ha. The J canal experimental section is 3.2 km long and was stocked at 100 kg/ha.

Weed control efficacy was evaluated by comparing random weed samples from the control and experimental sections. Divers using SCUBA collected all vegetation within 0.1 m^2 quadrats. Samples were then dried and weighed and classified as to species composition.

RESULTS AND DISCUSSION

An analysis of weed biomass differences in Canal O5C revealed a 5% weed biomass decrease in the stocked area when compared to the control section. However, when an analysis of the downstream stocked area was compared to the upstream stocked area, a 60% aquatic weed biomass depletion was observed in the downstream area. This may be attributed to high canal flow rates with subsequent dislodging and transportation of aquatic weeds adjacent to the screen barrier where most fish congregated for the summer. This would result in poor fish dispersal and therefore reduced feeding along canal weed beds. Construction activities within this canal reach during the late summer may have also resulted in poor feeding performance.

Canal J treated areas were reduced by 64% dry weight weed biomass when compared to un-stocked control areas.

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Canal	Stocking Density (kg/ha)	Weed Biomass (g/m^2)		Survival Rate (%)	Weight Increase (%)
		Control	Stocked		
O5C	102	392	372	88.7	34.5
J	100	337	122	92.7	32.5

Fish survival in Canal O5C was 88.7% with an increase in weight of 34.5%. Although fish growth increased in both canal study areas body condition (weight/length relationship) decreased by 7.7% in Canal O5C and 13.5% in J. This would suggest a decreased growth performance even though abundant aquatic weed biomass was prevalent. This may be due to excessive flow rates, inadequate cover, poor fish dispersal, shallow water depths and high disturbance factors.

RECOMMENDATIONS

Fish stocking densities should be increased to 200 kg/ha for 1995 to achieve increased aquatic weed biomass control.

Techniques should be developed to improve fish dispersal and overhead cover.

TRIPLOID GRASS CARP DUGOUT STUDIES PHASE II (1994)

S. Jonas, D. Lloyd, J. Stewart[1]

INTRODUCTION

The objective of this multi-agency research project is to study the impact of sterile triploid Grass Carp (Ctenopharyngodon idella) on problem aquatic vegetation and water quality in the farm dugouts of Alberta.

The majority of farm dugouts in Alberta have a multiple-use function. Alberta has approximately 14,000 active farm dugouts which store water for domestic use, livestock watering and irrigation. The same dugout may be used for recreation, aesthetic enjoyment and provide a sport or commercial trout fishery for the farmer.

This report presents the preliminary findings of the first year of a two-year study.

METHODS

Weed Control Efficacy Studies

Six dugouts were selected and partitioned into halves to establish control (unstocked) and experimental (stocked) sections. Grass carp were stocked in the experimental sections at densities of 169, 195, 308, 347, 512 and 514 kg/ha.

Divers collected aquatic plant standing crop biomass in the dugouts by clipping and removing all vegetation within 0.1 square metre quadrats at randomly selected points. Samples were assessed as to species composition and then dried and weighed. Dried samples are expressed as grams per square metre and an assessment of efficacy was obtained by comparing samples in the control and experimental sections.

Water Quality Studies

Two separate sets of paired dugouts of similar size and weed biomass were selected for the study. Each pair included one experimental dugout and one control dugout located in close proximity to each other. The two experimental ponds were stocked at 225 kg of fish per ha, the control ponds remained un-stocked. All four ponds were sampled monthly for coliform, faecal coliforms, nutrient chemistry (dominant anions - nitrites, nitrates, phosphates etc.; dominant cations - calcium, potassium, iron etc.), total hardness, total alkalinity, total dissolved solids and heavy metals.

Related analysis was conducted on turbidity, Secchi disc transparency, temperature, dissolved oxygen, chlorophyll a and sediment chemistry. Data was also

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collected on aquatic invertebrate densities, species composition, species diversities and pre and post-season changes in aquatic weed biomass.

RESULTS AND DISCUSSION

Weed Control Efficacy Studies

Aquatic weed biomass in grams dry weight per metre squared in experimental compartments ranged from 62.3% to 100% less than the control areas. The average reduction of aquatic weed biomass in all six dugouts was 85%. Close to one hundred percent weed control was achieved in two of the dugouts within six weeks of stocking. See Table 1. Three of four dugouts that were stocked in excess of 300 kg/ha controlled aquatic plant biomass. One dugout (Hetesy) was stocked at a density of 514 kg/ha and had only 62% aquatic weed removal. This may be attributed to the composition of the aquatic plant community, resulting in differential palatability of aquatic weed species.

Dugout	Stocking Density (kg/ha)	Control Section (g/m^2)	Stocked Section (g/m^2)
Gergely #1	169	207	66
Paint	195	199	46
Giffen	308	1573	1
Kelly	347	1399	0
Old Kennedy	512	174	1
Hetesy	514	1835	692
Average		898	134

Table 1. Average Aquatic Plant Biomass - Summer 1994.

An average fish survival rate of 91.5% occurred in the dugouts between May and October. During that same time period average length increased by 29.1% and weight increased by 67.1%.

Water Quality Studies

For the spring and summer of 1994 it appears that the presence of grass carp in stocked water bodies had no significant impact on nutrient water chemistry and coliform bacteria.

A precipitous decline in three heavy metals (Aluminum, Chromium and Zinc) was noted in July and August for one of the stocked dugouts (Malec). In theory, these metals should be removed from the water column by the macrophytes and in turn incorporated into fish flesh when the aquatic weeds are consumed by carp.

Grass carp, therefore, might be used as a means of removing heavy metals and other contaminants from degraded aquatic ecosystems.

Between July and September there was 100% removal of aquatic plant biomass in the stocked dugouts, whereas the unstocked dugouts showed increases of 142% and 202%. The decrease in plant biomass in the stocked ponds resulted in increases in benthic invertebrate species (due to weed removal) when compared to control environments with high weed biomass and also resulted in lower invertebrate species diversities.

Fish survival in the stocked water quality ponds were 81.8% and 100%, while weight growth increases were 49.7% and 184.4%.

CONCLUSIONS AND RECOMMENDATIONS

The results given only indicate the first year's progress of a two-year study. A detailed report will follow upon completion in 1996.

IRRIGATION - PRODUCTION

IRRIGATION MANAGEMENT OF DRY BEANS - 1994

Robert Riewe P.Ag.,[1] David Coutts,[1] Brian Handerek,[1] Tom O'Reilly,[1] Leigh Morrison, P. Eng.[1]

INTRODUCTION

This field survey was initiated in 1991; 1994 was the first year that any meaningful data was obtained. Irrigation was drastically limited in 1991 because of rain; the crop was destroyed in 1992 by snow and frost and in 1993 by frost and hail.

Dry edible beans are an important cash crop in the irrigated region of southern Alberta. There are differing opinions on what type of irrigation schedule will produce maximum yields. Some recommend allowing the soil moisture to fall to the wilting point prior to bloom and at the later pod filling stage. Others recommend maintaining 50% of Available Moisture (A.M.) as a minimum soil moisture level. Alberta Agriculture currently recommends maintaining 60% of A.M. as a minimum level for all growth stages[2]. In order to study the effects of different irrigation schedules under field conditions, this study was initiated.

Objectives

To evaluate the present irrigation management practices of dry bean production.
To develop irrigation management recommendations for dry beans.
To update the present irrigation management factsheet for dry beans.

METHOD

Moisture monitoring sites were selected in co-operating farmers fields. The fields were located in a band along highway #3 from Coaldale east to Medicine Hat. Each site was chosen to be representative of the entire field and a marker flag was installed at each site. A rain gauge was used to measure irrigation. Additional rain gauges were located just outside of the irrigated area to measure precipitation. Canola oil was used in these gauges to prevent evaporation.

Once the crop was planted, soil moisture monitoring was carried out weekly using both the feel method and the neutron moisture probe. Samples were taken within a 4 metre radius of the marker flag at 25 cm increments to a depth of 125 cm. Soil moisture was recorded as a percentage of available moisture. Rainfall, net irrigation amounts, and average soil moisture levels for both the top 50 cm and for the 100 cm root zone were recorded. Other data recorded included crop stage,[3] chemical applications, stand appearance, presence of bloom, harvest losses, and any perceived problems with the crop and field conditions.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta T1J 4C7

[2] Alberta Agriculture, 1987. Agri-Fax Irrigation Management of Dry Beans. Agdex 561-12.

[3] Colorado Dry Bean Production and IPM. Bulletin 548A. Colorado State University Cooperative Extension and Agricultural Experimental Station.

RESULTS

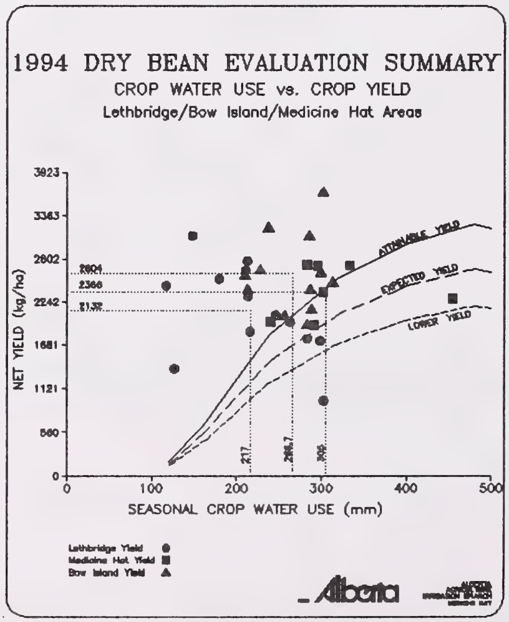
In 1994, 33 fields were monitored with an average net yield of 2358 kg/ha. The corn heat units from May 20 to August 31 were marginally above average at 2036. The average seeding date was May 25 and the average cutting date was Aug 27 for a total of 94 growing days.

TABLE 1 CONSUMPTIVE USE AND CORN HEAT UNITS

	1994 Measured Consumptive Use mm			Corn Heat Units May 20 - Aug 31	
	Min.	Max.	Ave.	14 yrs. ave.	1994
Medicine Hat	240	454	305	2058	2051
Bow Island	209	314	267	2069	2126
Lethbridge	117	303	217	1908	1931

The consumptive use was less than expected from established crop response curves. The expected seasonal consumptive use is 380 mm. The average measured seasonal consumptive use for all fields in the study was 256 mm. Figure 1 shows the relationship of crop yield to moisture use for all the fields in the study. There is a high degree of variability because of a lack of control of high water tables, surface water ponding, sclerotinia infestations, weeds, and hail.

**FIGURE 1
WATER USE VS
CROP YIELD**



On average soil moisture was maintained above the recommended 40% allowable depletion level for the entire growing season. This was true for the 50 cm soil depth as well as the 100 cm depth. Generally farmers are not creating conditions of moisture stress at any time or for any reason. Figure 2 shows that precipitation in June was sufficient for most of the crops requirements with minimal irrigation applied. Beginning at July 10 during the flowering stage irrigation was necessary to maintain suitable soil moisture conditions.

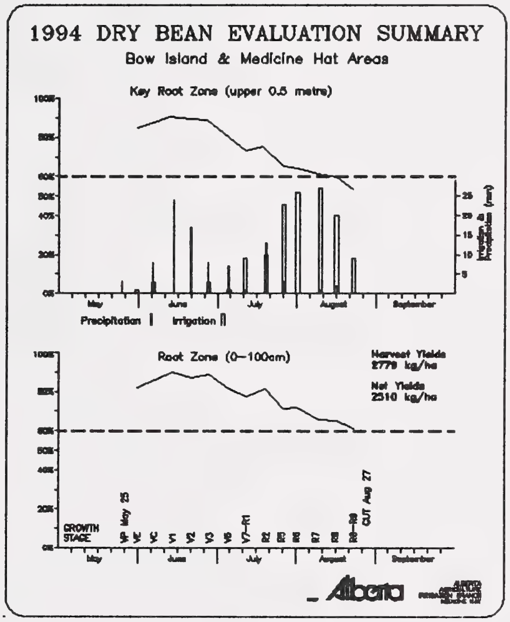


FIGURE 2 SOIL MOISTURES

Figure 3 shows the number of irrigations and the amount applied according to the type of equipment used. Pivots made on average 7 circles and applied 154 mm, side wheel rolls (SWR) made two passes and applied 124 mm.

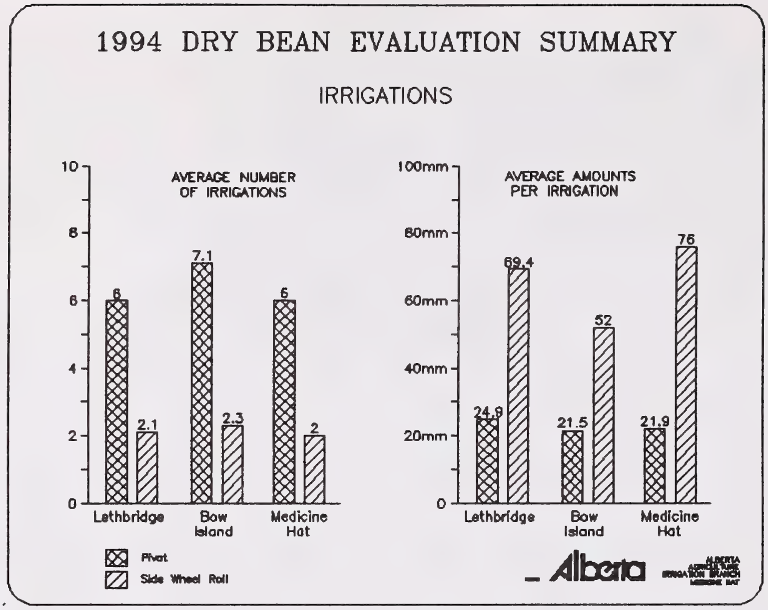


FIGURE 3 IRRIGATIONS

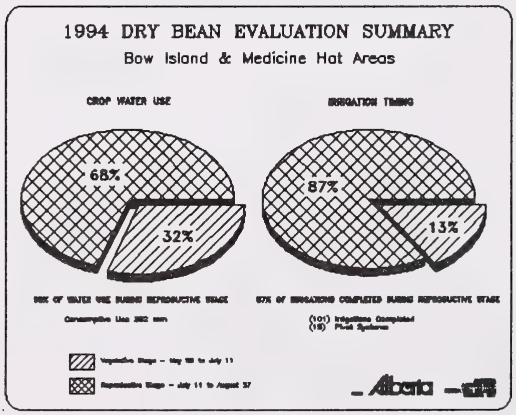


FIGURE 4 IRRIGATION PRACTICES

Most irrigation took place during the reproductive stage when 68% of the seasonal water requirement was used. From flowering to pod set 192 mm was required by the crop. During this period 87% of all the irrigation took place which was 121 mm net.

DISCUSSION

There is a high degree of variability in the data on measured seasonal consumptive use and yield. This is the result of production factors that were beyond our control because of field conditions. In one case estimated yield losses because of sclerotinia was 52%. Other factors were: hail damage, high water tables, and irrigation in excess of crop requirements. We suspect that the measured consumptive use values were lower than can be expected.

Research is required under controlled conditions to determine daily and seasonal consumptive use.

CONCLUSION

This field survey identified the high variability in data because of uncontrollable variables under field conditions. Farmers are applying more water with pivots than with side wheel rolls and generally soil moisture conditions are good for the entire growing season.

QUALITY OF FEEDLOT MANURE FOR IRRIGATED CROP PRODUCTION

Gregg Dill, P.Eng.[1], Keith Boras[2]

Cooperators: Cor Van Raay Farms Ltd.
Nolan Cattle Company Ltd.
Turin Feeders Ltd.
Porcupine Corral Cleaning (1992) Ltd.
Agriculture and Agri-Food Canada (AAFC)

INTRODUCTION

Although there are approximately 400,000 cattle in feedlots in the County of Lethbridge No. 26 there is no information on the nutrient value of the manure that is produced in these feedlots. Due to a lack of local information, published values have been used to estimate the quality and quantity of manure hauled from feedlots. Many of these numbers have been developed in areas with different climate and different feeding regimes. In 1993 the County committed part of their CAESA funding to supplying this information over the next four years. Three feedlot operators were contacted as cooperators. Since Agriculture and Agri-Food Canada (AAFC) has been working with land application of manure for over 20 years they were consulted in developing the project. This is the second year of a four year study.

The management of manure application on irrigated land is important to allow farmers to maximize the benefits of this often overlooked resource. The information will enable feedlot operators to make the best use of manure as fertilizer and, hopefully, convince farmers who don't have livestock that the manure has value and is worth paying for.

The objective of the project is to determine the quality and quantity of manure in finishing feedlots in southern Alberta. The information will be used to make water management recommendations to irrigators and for planning purposes in the County of Lethbridge. Ideally, the analysis of manure from the three feedlots will support the assumption that the analysis also applies to all pens in all other feedlots in the County year after year. To find out if this is true six pens were selected in lot A and four pens each in lots B and C. Manure was sampled in the bedding pile and the manure pack separately.

METHODS

In 1993 and 1994 manure samples were collected from all pens and analyzed for N,

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P, K and S as well as other elements. The number and weight of cattle in the pens were recorded monthly starting after the pens were cleaned in the fall of 1993. The manure was weighed as it was hauled from the pens and the amount of bedding was recorded or estimated for each pen. The time required to haul manure from each pen in lot A was recorded. This information was used to determine the amount of manure per head per day and approximate cost per tonne.

The data was analyzed statistically by AAFC who also assisted in the interpretation. The data was analyzed as a factorial experiment although the design did not follow any standard procedure.

During 1993 procedures to collect the data were developed and background information collected. The manure analysis was required to be consistent with published data was selected in cooperation with the Alberta Agriculture Soils & Animal Nutrition Lab. All pens were cleaned completely and the bedding piles measured. Simple tasks often become complex - we could not find a sampler to collect samples so one was designed and built. Manure samples were analyzed from all three feedlots. The manure was weighed as it was hauled from the pens in two of the feedlots. Although we collected data, we did not collect cattle numbers to determine the amount of manure per animal.

In 1994 the number and weight of the animals in each pen was recorded to determine the amount of manure per head per day. Three samples of the bedding pile and the manure pack were taken in each pen and analyzed for N, P, K and other elements. A Dutch auger was used to collect samples due to the more normal dry conditions in the pens.

<u>Nutrient Analysis</u>

The samples collected in 1993 and 1994 were analyzed for available and total N, P, K and S as well as other nutrients. The slow release amounts of N, P, K and S are not completely available for crop production even over several years but some will be available in the first year. The amount available depends on several soil related factors. Unfortunately, the 1993 analysis for available amounts was prepared incorrectly and only the nitrogen analysis can be reported for that year.

RESULTS

Results for 1993 and 1994 are reported for two lots for total N, NH_4, P, K and S. One cooperator lost interest after 1993 and was replaced in 1994. These results indicate NH_4, K and S are different among lots. Total N levels may also be different. Levels of NH_4 and S were different from one year to the next. Levels of N, P and K may also be different. Differences may be due to feed rations, weather, age of cattle as well as several other factors.

NH_4 levels were different from lot to lot in 1994 samples. Levels of S and SO_4 may be different but sufficient information was not collected to identify a difference. The amount of ash (soil) in the samples was in the range of 30 to 40 per cent on a wet weight basis.

When the samples from each feedlot were analyzed separately, the levels of NH_4, P and S were different in lot A. There may also be differences for PO_4 and total N. No differences among pens were identified in lot B. In lot C differences among pens were identified for all nutrients except total N.

Figure 1 shows the average total N, P, K and S and the range of values for samples collected in 1994. The N, P, K and S are expressed as Total N, P_2O_5, K_2O and SO_4 respectively. The maximum values are often two to four times the minimum values giving an indication of the inconsistency of manure in a feedlot. Figure 2 shows similar information about the available nutrients in the 1994 samples. The range is generally the same as in Figure 1, but in some cases it is as high as 20 times the minimum value.

Figure 1.

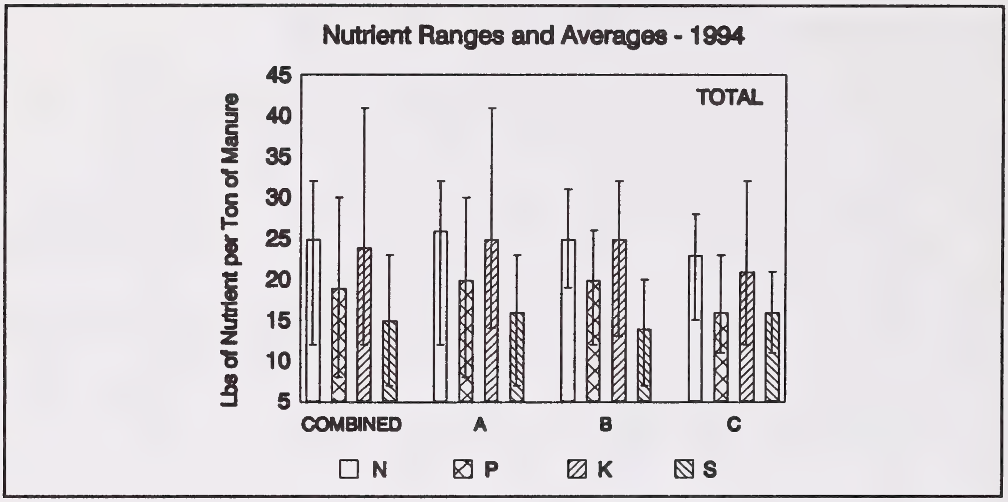
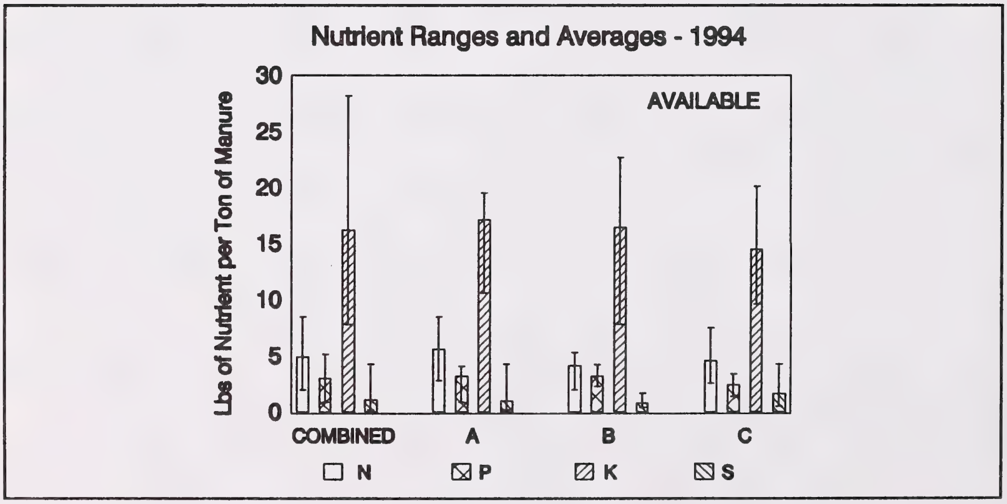


Figure 2.



The weight of manure hauled from each pen was monitored in lots A and B. The average for lot A was 11.5 pounds per head per day with a range of 10.2 to 14.7 for five pens. The average for lot B was 11.5 with a range of 9.5 to 13.2 for four pens. These

values are much lower than the 15 pounds per head per day currently being used. Based on custom rates, the average cost of hauling manure from lot A was $2.70 per tonne.

DISCUSSION

The values presented are for manure in the feedlot pens and do not account for any losses from handling and incorporating in the field. Guidelines exist for these losses but have not been verified for Southern Alberta. It is recommended that a manure analysis be done to choose the tons per acre to spread.

The equivalent value of urea and P_2O_5 in a ton of manure is $5 to $20 before losses and efficiencies are considered. Although it is difficult to estimate the amount of nutrients the crop will be able to use it is obviously a resource to be managed and not a waste product. Manure also contains other nutrients and micronutrients such as potassium, sulphur, zinc, copper, manganese and iron as well as organic matter which contribute to crop growth and have value. Most of the nitrogen in manure is in organic form requiring microbes to break it down which makes it a slow release fertilizer. For maximum return from the nutrients and organic matter, manure should be applied to eroded fields where the benefits of reclamation will return the highest dollar value for the manure. The benefits of this management practice can justify hauling manure greater distances.

CONCLUSION

This is year two of a four year project and the observations and conclusions made now will change as more data is collected.

Thanks to Dr. Chi Chang of AAFC for his assistance in project design and interpretation of the results, Toby Entz of AAFC for running the statistical analysis and assisting with the interpretation and the Alberta Soils and Animal Nutrition Lab for analysing the many odorous manure samples.

Thank you for your support of this project which will benefit Southern Alberta and the cattle industry as well as the County of Lethbridge.

CHEMIGATION TRIALS USING A LOW PRESSURE CENTRE PIVOT

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INTRODUCTION

This is the second year of a two year project to conduct a chemigation trial using a three tower pivot at the Agriculture and Agri-Food Canada research substation in Vauxhall. The project design and equipment were described by Cook in the 1993 Irrigation and Resource Management Report. The objectives of the project were:

1) Obtain information to support the minor use registration of Metribuzin and EPTC for weed control in potato crops using chemigation techniques.

2) Obtain information to support the minor use registration of Cypermethrin for control of Colorado potato beetle in potato crops using chemigation techniques.

3) Assess the effectiveness of biological control using Bacillus Thuringiensis (Bt) to control Colorado potato beetle in potato crops.

4) Compare chemical treatment (Cypermethrin) and biological control (Trichogramma Brassicae) for control of European corn borer in corn.

METHODS

The herbicide treatments were the same as the 1993 treatments as follows:

1. Control

2. Preplant ground applied and incorporated tank mix of Metribuzin at 0.28 kg active ingredient/hectare (ai/ha) and EPTC at 3.4 kg ai/ha

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3. Pre-emergent chemigated tank mix of Metribuzin at 0.28 kg ai/ha and EPTC at 3.4 kg ai/ha
4. Pre-emergent chemigated tank mix of Metribuzin at 0.55 kg ai/ha and EPTC at 3.4 kg ai/ha
5. Post hilling chemigated tank mix of Metribuzin at 0.28 kg ai/ha and EPTC at 3.4 kg ai/ha
6. Post hilling chemigated application of Metribuzin at 0.28 kg ai/ha

Treatment #2 was done May 26 prior to seeding. Treatments #3 and #4 were applied June 9 with 8 mm of water. Treatments #5 and #6 were applied July 5 with 8 mm of water. Treatment #6 received 0.21 kg ai/ha of Metribuzin due to an error in calculation of Metribuzin concentration. Rainfall for the season was 154 mm and 269 mm of irrigation water was applied. All plots received an equal amount of water.

The insecticide trial compared chemical control (Cypermethrin) and a parasitic wasp (Trichogramma Brassicae) release to control European corn borer (ECB). A control (no treatment) was located adjacent to the wasp release site. Wasps were released weekly at a rate of 100,000 wasps/week for six weeks starting three days after the first moths were caught in the pheromone traps. During the last week of August, 480 plants were examined in situ for ECB infestation.

Plots were prepared to evaluate the effectiveness of Bt and Cymbush to control the Colorado potato beetle. Insectigation was done but an insect population did not develop large enough to do a comparison.

RESULTS

This is the final year of a two year project. Weed control results for 1993 may have been affected by hilling which by its nature is an effective weed control practice. In 1994 none of the treatments caused any crop injury. Metribuzin applied late pre-emergence provided excellent control of Redroot Pigweed. Post-emergence applications coincided with advanced weed growth and weed control was consequently inadequate. Yield for the weedy check and the post-emergence Metribuzin treatment (#6) were significantly lower than the highest yield (#4). Specific gravity was unaffected. The results from the pre-emergence incorporated ground application did not differ from the pre-emergence chemigation treatments.

Market yields are the average of six 5-square metre samples, two from each replicate. Average market yields were 35.4, 43.8, 41.7, 49.2, 37.5 and 34.7 tonne/ha for treatments one to six respectively.

Initial indications are parasitic wasp control of European corn borer did not differ from the chemical control applied. Based on the ECB male moths caught in the pheremone traps, the infestation in the control section was lower than expected (Table 1). This may be due to the migration of wasps from the adjacent section where wasps were released. Although the result was inconclusive, the high infestation rate in the chemical control treatment may be an indication of chemical interference with the release. This is worth pursuing with a more secluded control treatment, probably using the chemical control treatment to segrate the control from the wasp treatment.

Table 1. European corn borer infestations

	Control	Chemical	Wasp
Plants Examined	480	480	480
Plants infested	5	10	6
Larvae found	10	14	7
Cobs examined	672	681	677
Cobs infested	10	14	7

CONCLUSION

Information was collected to support minor use registration of Metribuzin and EPTC for weed control in potato crops. Colorado potato beetle infestations were not high enough to collect information on Cypermethrin or Bacillus Thuringiensis for control of Colorado potato beetle in potato crops.

Further work is required to investigate the use of parasitic wasps to control European corn borer in corn crops.

ACKNOWLEDGEMENTS

Thank you to the Agriculture and Agri-Food Canada field staff at the Vauxhall substation and the Agriculture, Food and Rural Development staff in Vauxhall for their assistance in this project.

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CONSERVATION - CROPPING AND TILLAGE

Sustainable Cropping Systems Research Study
Three Hills Site

E. Oosterhuis and T. L. Jensen[1]

INTRODUCTION

In Alberta, crop rotation effects on yields and field productivity, have received a great deal of attention. Long term rotational studies by Agriculture and Agri. Food Canada and the University of Alberta research scientists began early in this century. These studies are located at the Lethbridge Research Center (Dark Brown soil zone), and at the Ellerslie (Black soil zone) and Breton (Gray soil zone) research farms. In 1991 work began on three new crop rotation studies; one at Bow Island (Brown soil zone), this one at Three Hills (Dark Brown - Black transition soil zone), and a third at Beaverlodge (Dark Gray soil zone).

The objectives of this study are as follows:

1. Evaluate the long term effects of various cropping systems (crops and crop rotations) on the productivity of the soils at the site. These rotations represent cropping systems that farm managers presently use or could use in this area.

2. Use the information gathered to help farm managers decide what cropping systems would be suitable on their farms where similar soil-climatic conditions exist.

3. Compare the results of this research site with results from the other 4 sites mentioned above. The experimental design includes appropriate crops and rotations as well as replicated and randomly assigned treatments so that the data from this site can be analyzed along with the data from the other sites.

METHODS

This long term rotational study, located next to the Three Hills airport , is a 10 acre site of provincially owned land in the M.D. of Kneehills. The experimental design consists of 20 main plots per each of the 4 replicate blocks. The 20 main plots are randomly assigned and each represents a specific phase of one of the 9 specific crop rotations assessed in the study. All crop rotations and fertilizer treatments were reviewed and selected with assistance from other members of the sustainable cropping systems committee. The 9 crop rotations are as follows:

- Continuous wheat
- Wheat - canola - barley - peas
- Fallow - wheat
- Green manure (peas) - wheat

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- Fallow - wheat - wheat
- Fallow - peas - wheat
- Continuous grass (brome) as a forage crop
- Continuous alfalfa and grass (brome) as a forage crop
- Fall rye - wheat - peas and oats silage

Each replicate block is split by the following 5 fertilizer treatments:

a. Manure (6 tonne per hectare)
b. Nitrogen plus phosphorous (60 kg N and 30 kg P per hectare)
c. Nitrogen only (60 kg N per hectare)
d. Phosphorous only (30 kg P per hectare)
e. No fertilizer

RESULTS AND DISCUSSION

The 1994 yield data was collected and recorded as planned. Total weights, grain weights and straw weights were measured and recorded. This was the third year of this rotational study and because each stage of every rotation is seeded annually it was possible to compare yields between rotations. Of the nine rotations selected, seven of the rotations include wheat in their rotation, therefore wheat yields were used as a comparison between the seven rotations. One of these rotations is "fallow - wheat - wheat" this rotation was split into two separate treatments, one measuring the yield of wheat grown after fallow, and the other which measured the yield of wheat grown after wheat. There was a total of eight different wheat treatments from within the seven different rotations. The wheat treatments are as follows:

<u>#. Wheat treatment:</u>
1. Continuous <u>wheat</u>
2. <u>Wheat</u>-canola-barley-peas
3. Fallow-<u>wheat</u>
4. Green manure-<u>wheat</u>
5. Fallow-<u>wheat</u>-wheat
6. Fallow-wheat-<u>wheat</u>
7. Fallow-peas-<u>wheat</u>
8. Fall rye-<u>wheat</u>-peas & oats

All of the crops seeded were treated with the appropriate fungicide or inoculant, and when the developing plants reached the proper leaf stage, incrop spraying was performed using suitable herbicides. The only plots that did not receive any herbicides were the "peas and oats" and "fall rye" plots in treatment 8. This rotation was selected as a "low input" rotation. All fallow treatments were cultivated approximately once a month to control weeds and conserve soil moisture.

Yields for the above 8 wheat treatments were analyzed Analysis of Variance. The results are graphed in Figure 1 on the next page. A different letter above each bar denotes a significant difference between treatments (ie. "a" is significantly different than "b").

The wheat yields for treatments 3, 5 and 6 were significantly higher than the remaining five treatments. treatment 3 had the highest yield of wheat at 2307 kg/ha, although it was not significantly different from treatments 5 and 6 which yielded 2216 kg/ha and 2125 kg/ha respectively. Treatment 8 had the lowest wheat yield (998 kg/ha) of the eight treatments and was significantly lower than all of the other treatments. Treatments 7, 4, 1 and 2 ranked 4th, 5th, 6th and 7th respectively and these yields were not significantly different from each other but were significantly higher than treatment 8.

A statistical analysis of the fertilizer treatments, for the wheat plots only, showed that N & P yielded the highest at an average of 1863 kg/ha. N Only yielded second highest at 1790 kg/ha. Both of these fertilizer treatments though not significantly different from each other, were significantly higher than the remaining three fertilizer treatments.

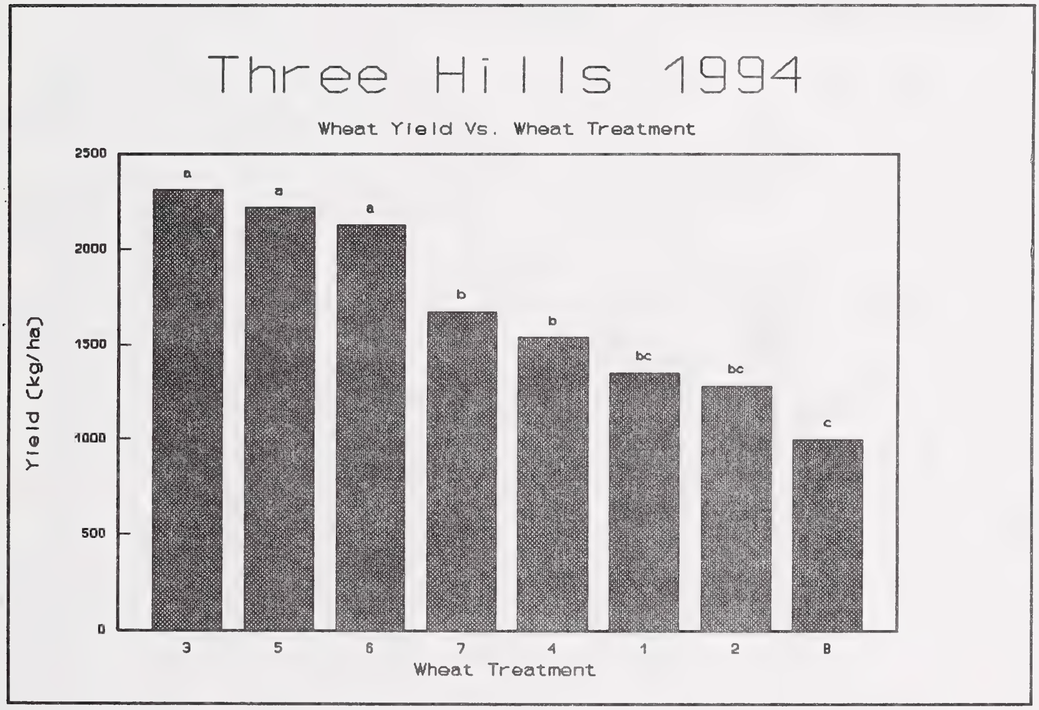

Figure 1 Values for each treatment labelled by the same letter are not significantly different at P=0.05.

There are two rotations which do not involve a wheat crop. These two rotations are continuous forage crops #7(continuous Brome grass) and #8(continuous Alfalfa and Brome grass). Dry matter yields for both forage rotations were analyzed as split-split plots. There was no significant differences between the two rotations nor between the five fertilizer treatments. The yields for both rotations and the five fertilizer treatments are graphed in Figure 2 on the next page. The only significant difference for the forage crops' dry matter analysis was that hay cut #1 significantly outyielded hay cut #2. The poor yield of hay cut #2 is probably due to low amounts of rainfall during the month of July in 1994.

Chart 1, below, lists the amount of rainfall for May through September during 1994 and the 30 year average between 1961 and 1990. This allows comparison between 1994 rainfall and the average amount of rainfall. There appeared to be above average moisture during May, August and September of 1994 in the Three Hills region, however, during June the amount of rainfall was 17% below the average amount and only half of the average amount of rainfall was recorded during the month of July.

Chart 1:

Rainfall (mm)	May	June	July	Aug.	Sept.
1994 year	74.4	56.4	35.1	110.7	58.9
(1961-1990 Average)	43.1	68.3	70.2	48.4	44.8

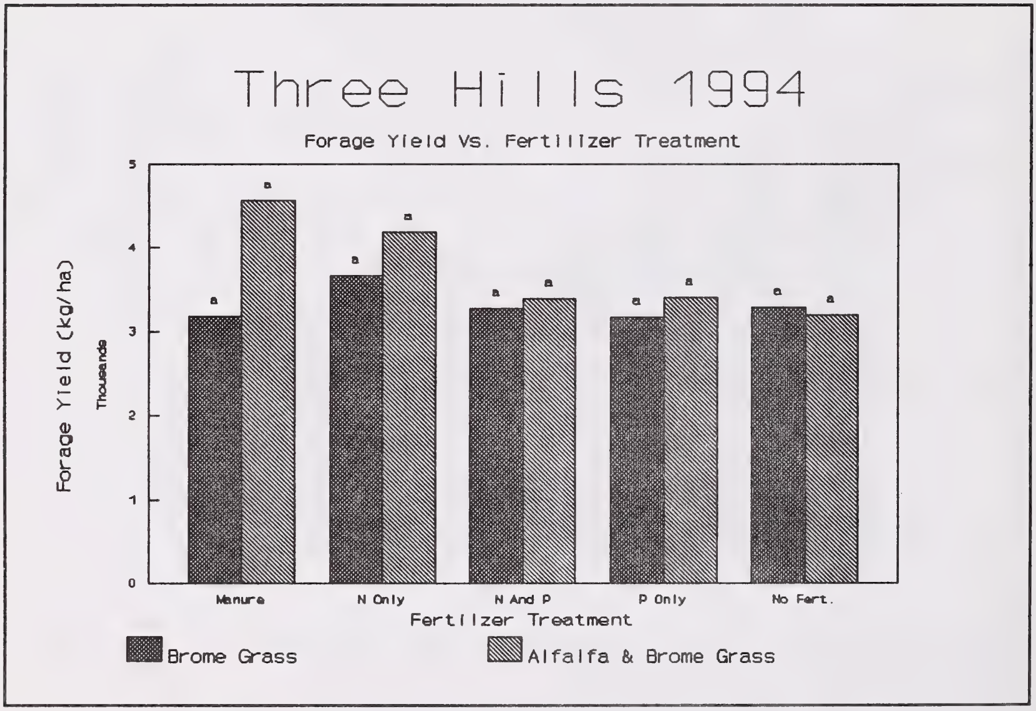

Figure 2 Values for each treatment labelled by the same letter are not significantly different at P=0.05.

The weather station is fully operational and measurements are recorded every hour. Environment Canada has been very helpful in setting up the station and organizing the data. All 1994 weather data has been sorted and recorded. Chart 2, on the next page, lists some of the weather data of agronomic importance during the growing season of 1994.

Chart 2:

1994	May	June	July	Aug.	Sept.
Total Rainfall (mm)	74.42	56.39	35.05	110.73	58.92
Minimum Air Temperature (°C)	-1.49	1.72	5.03	3.13	-0.58
Maximum Air Temperature (°C)	27.48	28.75	32.48	34.18	29.61
Minimum Soil Temperture (°C) @5 cm Depth (Date)	10.91 (6th)	14.79 (16th)	18.56 (6th)	16.44 (27th)	14.75 (21st)
Minimum Soil Temperature (°C) @10 cm Depth (Date)	7.07 (6th)	11.54 (16th)	13.86 (6th)	11.66 (27th)	10.56 (21st)

During the fall of 1994, cores were sampled from each plot to a depth of 0.6 meters. The samples were separated into three increments: 0 - 15 cm, 15 - 30 cm, and 30 - 60 cm. Only three of the four replicates were sampled to cut down in soil loss, as well as labour and analysis costs. This year replicates 2, 3 and 4 were sampled and the available N,P K, and S nutrient content was determined. The available plant nutrient levels were analysed, using Analysis of Variance (ANOVA), and recorded.

During the spring of 1994, prior to seeding, 1.2 meter cores were sampled and soil moisture levels determined. Only two replicates were sampled this year as heavy rain forced us to stop sampling. The samples were divided into 5 increments: 0 - 15, 15 - 30, 30 - 60, 60 - 90, and 90 - 120 cm depths. The moisture contents, for the two replicates sampled, were averaged and recorded.

CONCLUSIONS

This year was the third year that these nine rotations were grown at the Three Hills site. Most of the rotations have completed their first cycle, the only exception is rotation #2 which is a four year rotation. A comparison of the wheat yields between seven of the rotations show differences at this early stage already, however, moisture was a limiting factor during mid summer. The effects of crop rotation on soil and crops seeded will become more evident in future years. After completion of several crop rotation cycles, comparisons can be made from one year to another and results should be more clear and informative. The yields were quite low in 1994 for the Three Hills rotational study. The low yields are the result of below average rainfall during June and July.

The wheat yield analysis showed that rotations 3, 5 and 6 had significantly higher yields than the remaining rotations. All three of these rotations involved a year of fallow prior to the wheat crop. This is because the wheat grown after fallow had more moisture available for crop growth than wheat grown after a previous crop. The weather data collected confirms that the amount of rainfall was low during June and very low during July, which can decrease a wheat yield substantially as this moisture is needed for the development of the kernel. The analysis of results also showed that the wheat yield in the low input rotation (wheat-peas & oats-fall rye) was significantly lower than all other rotations. This poor yield could be due to an allelopathic effect from the fall rye. The same trend was noticed in the wheat yields of 1993.

The analysis of the fertilizer split plots showed that two fertilizer treatments, "N and P" and "N Only" resulted in significantly higher yields than the remaining three fertilizer treatments. "N Only" had the best yield response and "P Only" had the worst. This was probably due to the fact that the soil has sufficient levels of phosphorous and when additional levels of phosphorous are added without additional nitrogen the balance of nutrients available to the crop is disrupted. This nutrient balance disruption could have a negative impact on crop growth. The manure fertilized plots will require a few more years to ensure proper mineralization and availability of nutrients for the crop plants grown.

CANOLA AND DIRECT SEEDING

E. Oosterhuis & T.L. Jensen[1]

INTRODUCTION

Two components of the agriculture industry in Western Canada have increased greatly over the past year. One is the amount of canola grown and the other is the amount of field crops grown Using direct seeding methods. Canola has increased from 10.2 in 1993 to 14.3 million acres in 1994 (3.6 and 5.0 million acres in Alberta respectively). Direct seeding during the same period increased 300% (1.5 and 4.3 million acres for 1993 and 1994 respectively. In some areas 15% of the land under cultivation was direct seeded.

Most of the direct seeded acreage is cereal crops and not canola. The reason is because the weed control strategies used when growing canola generally include soil incorporated herbicides. For example, Trifluralin (TREFLAN) and Ethylfluralin (EDGE) are two such herbicides. Both herbicides require soil incorporation (tillage) as per the licensed registration. The minimum of two tillage operations are required to incorporate the above mentioned herbicides does not fit into a direct seeding system. Farm managers who use direct seeding would like to direct seed their canola crop. Some have done so with some success, although they admit that weed control options for direct seeded canola are lacking. This situation will not always be this way.

There are some promising developments in herbicidal weed control that would fit well with direct seeding. First, PURSUIT herbicide may be able to be used successfully under direct seeding as a post-emergent application on PURSUIT tolerant canola cultivars. PURSUIT is used successfully for the growing of soybeans under direct seeding in the US and Eastern Canada and for growing of field peas in Western Canada. Second, on-going research and development looking at the use of fall applied, granular EDGE, spread on the surface of a residue covered field that is direct seeded the next spring using no pre-plant tillage.

Previous research has shown that the yields of canola were as high and often higher for direct seeding compared to conventional tillage. These results were obtained even though no post emergent herbicides were used for the direct seeded canola while soil incorporated herbicides were used under the conventional tillage treatments. The yield advantage for direct seeded canola was most observable in drier years. This is because the extra conservation of moisture under direct seeding improved crop growth compared to when tillage was used. The potential to successfully grow canola under direct seeding by using direct seeding and the herbicides mentioned above is promising.

A direct seeding of canola research study has been organized in conjunction with Pioneer Hybred, Cyanamid, and the Alberta Agriculture Research Institute. This research will help producers adapt direct seeding technology for the growing of canola. Our goal is to show farmers that they can reduce input costs because of lower labor costs, less fuel usage, decreased investment in tractors and equipment and less soil erosion losses.

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Producers outputs will increase because of higher yields, due mainly to improved moisture conservation under direct seeding.

METHODS

Two suitable sites for this research have been arranged and the field plots will be seeded in 1995 and 1996. One of the sites is on a deep Black Soil at the U of A research station, the other site is on a Gray Soil near Warburg. All fall work has been completed as needed on the the sites, they have been staked, soil samples taken, and the samples analyzed for fertilizer recommendations for the 95 growing season. Four site years of results will be gathered. A split-split plot design will be used with four replicates at each site. The experiment will consist of two main tillage plots that will be split by two canola cultivars, and further split by four herbicide treatments.

The tillage systems that will be researched are conventional and direct seeded. The conventional tillage will consist of one fall discing followed by two passes with a chisle plow equipped with sweeps and harrows in the spring. The plots will then be seeded with a Harmon airdrill equipped with hoe openers. The direct seeded treatment will consist of no fall tillage, a pre-plant application of ROUNDUP (1 l/acre) and then seeded as above.

The two canola cultivars that will be seeded are of the Brassica napus species. One cultivar will be a suitable non-PURSUIT tolerant argentine canola. The other cultivar will be a Pioneer Hi-bred PURSUIT tolerant canola.

The four herbicide treatments will consist of two post emergent treatments, one fall applied pre-plant emergent and a control. One of the two post emergent treatments will be PURSUIT and the other POAST plus MUSTER. The fall applied pre-plant emergent will be granular EDGE with no incorporation on the direct seeded treatments but incorporated under conventional tillage. The control treatment consists of no pre-plant or post emergent application, except for the direct seeded treatment which will include ROUNDUP applied before seeding.

This research design will result in 16 unique combinations of tillage type * canola cultivar * herbicide. It is anticipated that the PURSUIT * Non-PURSUIT tolerant combination under both tillage and direct seeding will result in severely damaged canola. This however will be useful to determine the potential to control volunteer canola with PURSUIT.

The field research will be conducted over the growing seasons of 1995 and 1996. During the January to April extension season, presentations will be given at farm meetings. In early 1996 some of the initial results will be presented and in early 1997 final results and conclusions will be presented. We will use the research results from this project to prepare extension materials (Agdex, bulletin, Agri-News article, and a final report for AARI) to advise to farmers who want to use direct seeding for canola production.

CONVENTIONAL TILLAGE AND DIRECT SEEDING OF FIELD PEAS

E. Oosterhuis & T.L. Jensen[1]

INTRODUCTION

The use of direct seeding is being adapted at a phenomenal rate. For example in Alberta and Saskatchewan the acreage of direct seeding increased 51% from 4.3 million acres to 6.49 million acres in 1993 to 1994 respectively (Monsanto Canada Surveys). All indications are that this trend will continue. It appears as though field pea production and direct seeding is a winning combination. The sooner we can generate firm research results and pass that on to farm managers, the sooner they will be able to increase production at reduced costs.

In 1993 Alberta producers seeded approximately 300,000 acres of Dry Peas. In 1994 the Dry Pea acreage seeded was 400,000 acres, an increase of 33 1/3%. Canada's total Dry Pea production increased from 1,250,000 acres in 1993 to 1,760,000 acres in 1994, an increase of 28.9%. The rapid increase in Dry Pea production is associated mainly with conventional seeding methods. We are currently conducting experiments to study whether or not field peas are well suited for direct seeding, in the past the majority of direct seeded crops were cereals such as barley and wheat.

New products (herbicides) and technology (seeding equipment) which could benefit the direct seeding of field peas are available and should be tested for their adaption in Alberta. Recently available Airdrills, equipped with narrow hoe-type openers, are ideal for direct seeding of field peas. New herbicides such as PURSUIT and new application methods for previously registered herbicides, such as surface applied EDGE in the fall, are apparently excellent methods of weed control for direct seeding of field peas.

METHODS

The experimental design includes four pea cultivars: Montana, Highlight, Radley, and Patriot. The certified seed will be inoculated and seeded into three different tillage systems: conventional, minimum, and direct-seeding. The conventional tillage system will consist of one tandem disc cultivation in fall followed by two spring cultivations using a cultivator equipped with chisel-plough sweeps and harrows. The minimum tillage system will consist of two cultivations, one in the fall the other in spring. The direct seeding method will not be cultivated instead it will be sprayed with ROUNDUP at a rate of 0.75 litres per acre. All plots will be seeded using a custom built, eight foot Harmon airdrill. These plots will each be split by four herbicide treatments: control, EDGE fall applied (no incorporation on the direct seeded plots), PURSUIT post emergent, and BASAGRAN post emergent. Field plots will be seeded in 1995 and 1996.

Field pea growth, and soil conditions, will be monitored and recorded throughout the growing season. Soil moisture levels will be sampled at 0.15 m increments to a depth of

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1.2 m at seeding time and after harvest, precipitation will be recorded and this information used to determine moisture use efficiency by each cultivar. Soil temperature at seeding depth will be measured at the time of seeding and each week, for four weeks. Crop emergence will be recorded 2 and 4 weeks after seeding. Days to maturity will be recorded for each variety * tillage * herbicide treatment. Square meter yield samples will be taken at harvest and after harvest soil nutrient samples will be taken from each plot.

In 1994 we evaluated, the four pea cultivars mentioned above, under three tillage systems (conventional, minimum and direct seeded) and split the plots by three herbicide treatments(control, BASAGRAN and PURSUIT. The results from this initial screening test showed that direct seeding significantly outyielded conventional and minimum tillage, therefore, field peas appear to be well suited for direct seeding.

Two sites have been prepared for field experimentation in 1995. One of these sites is located near Warburg and the other is located on an experimental farm, belonging to the U of A, in Edmonton. Yield data will be analyzed during the fall of 1995 using analysis of variance with a split-split plot design. The winter of 1995-1996 will be spent preparing articles for Agri-News and preparing a progress report. A renewal application will be submitted during the winter and preparations made for 1996 for Matching Grant Funding in cooperation with Dow Elanco.

Field experiments will be repeated during the growing season of 1996 to allow four site years of data to be gathered. Data will be analyzed during the fall of 1996. In January of 1997 a summary article will be prepared for Agri-news. During February a paper will be written and submitted to a Scientific Journal. In March a bulletin for farm public use and a final project report for the Alberta Pulse Growers Commission, Dow Elanco, and the Alberta Agriculture Research Institute (AARI) will be completed.

The rapid increase in field pea production in the last two years, and the positive results from the direct seeding of peas experiment show that more research of direct seeding of field peas is warranted. We will evaluate new and upcoming direct seeding systems for field peas on a production and economic basis and share project results with farm managers by publishing extension bulletins and presenting results at field tours, conferences and producer meetings.

NO-TILL SEEDING OF BARLEY INTO SOD

Jeff Prochnau and Tom Jensen[1]

INTRODUCTION

The costs involved in converting hay or pasture fields into cereal crop production are high and time demanding. Intense tillage operations such as: ploughing, heavy discing, several conventional type cultivations, and harrowing are needed. These tillage operations are costly and allow the fields to become susceptible to wind and water erosion.

No-tillage or direct seeding of barley into a previous forage stand without pre-seeding tillage is possible using a direct seeding disk seed drill (eg. John Deere 750 series). Direct seeding with this type of seed drill lowers the operating costs and virtually eliminates the risk of soil erosion on the cropped land. In Canada's Parkland region of the Prairie Provinces, many mixed farm operations use a pasture-cereal or hayland-cereal rotation in their farm plan. However, there is little available information on converting hayland into a cereal crop using direct seeding practices within the Prairie Provinces.

To help develop information on this topic a research project titled "No-Till Seeding of Barley into Sod" was initiated in 1993, by the Conservation & Development Branch of Alberta Agriculture, Food and Rural Development. Funding was provided through the Alberta Agricultural Research Institute's Farming for the Future Program.

METHODS

The "No-Till Seeding of Barley into Sod" project is at three sites within central Alberta: near Innisfail, Onoway, and Viking. Innisfail and Onoway were previously a pasture while the Viking site was previously a hay field of alfalfa and bromegrass. The sites near Innisfail and Viking are on loam textured Black soil. The Onoway site is on a clay loam textured Gray soil. Each site has 4 tillage treatments replicated 4 times in a randomized complete block design. All seeding was done using a John Deere 752 drill. The 4 tillage systems evaluated were:

1) <u>CONTROL</u> direct seeding without tillage or a preplant herbicide application but included post emergent spraying for broadleaf weeds.

2) <u>HEAVY DISCING</u> two operations, followed by 2 passes with a cultivator, harrowing, seeding and post emergent spraying as above.

3) <u>NO-TILL</u> seeding, following an application of ROUNDUP (1 L/acre) one week before seeding and including post emergent spraying.

4) <u>PLOUGHING</u> followed by 2 disc operations, one pass with a cultivator and harrows,

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seeding and post emergent spraying.

In 1994, new replicate blocks were seeded adjacent to existing sites on May 26. The existing plots that were ploughed or disced in 1993 were cultivated in the fall of 1993 and again in the spring of 1994. The no-till plots stayed the same and in addition the control plot received an application of ROUNDUP one week before seeding. All these plots were seeded to measure barley growth during a second year after a forage stand.

The new replicate blocks seeded in 1994 were conducted with 5 different rates (0, 30, 60, 90, and 120 kg/ha) of nitrogen to determine the yield response to nitrogen.

All three sites were prepared for seeding during the third week of May in 1993 and 1994. This allowed the forage grasses to grow sufficiently to be controlled with ROUNDUP.

The quality of the seed-bed was determined by measuring soil temperature at seed depth, bulk density measurements, and the emergence of crop plants (# of plants per 1 m of seedrow) at 2 weeks after seeding. Observations and photographs of weed control were monitored throughout the season. Growth stage of the crop was recorded bi-weekly for 2 months after seeding. The observations included counts of nodes, leaves, tillers, flag leaf stage, and dry matter weight for 2, 1 metre length rows. At harvest the total dry matter yield of top growth, grain yield and straw yield were recorded. The border area around each replicate block was mowed as required.

RESULTS

1993 was the first year of the 2 year study. There was both a fertilized (50 kg/ha N) and non-fertilized sub treatment for each tillage type. The barley growth on the control treatments, both fertilized and non-fertilized was so poor that no samples were taken. Competition from the existing forage stand completely choked out the barley crop. The 1993 grain yield results show that no-till seeding yields lower than the disced or ploughed treatments (Figure 1). At Innisfail in 1993 there was a difference between the no-till treatment and disced treatment for the fertilized yields. At Viking in 1993 there was a significant difference between the no-till treatment and disced or ploughed treatments for the fertilized yields (Figure 1).

The yields for 1994 show that barley under no-till the second year is comparable to conventional tillage methods. At our Innisfail site, barley seeded under no-till in 1993 and 1994 yielded approximately 94% of plots disced in 1993 and cultivated in 1994 (Figure 1). This Figure 1 shows that after 2 years there was no significant difference in yields when no-tilled, disced or ploughed in the first year (1993). The other 2 sites at Onoway and Viking both showed similar results.

All the grain yields were calculated assuming 48 pounds of barley per bushel. Analysis of Variance was used to analyze grain yields followed by Duncan's Multiple Range Test at a 95% confidence level.

Based on the first year of sampling in 1993, the disced treatment performed the best at all three sites. A visual inspection showed that discing and ploughing had less grass and broadleaf weed growth compared to the no-till seeding. Bromegrass and creeping red fescue were two grass species that provided strong competition to the barley in the no-till treatments.

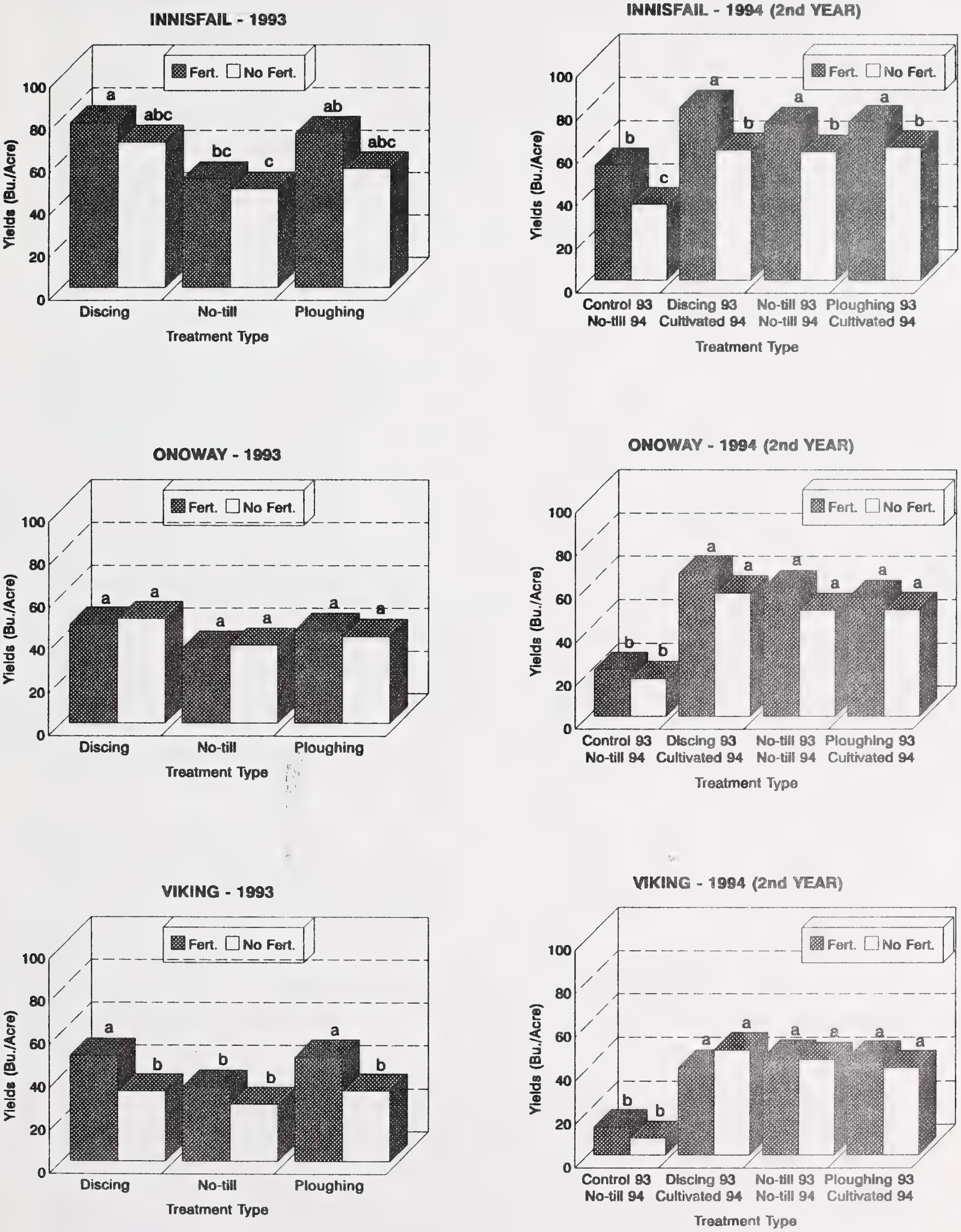

Figure 1. Comparison of grain yield in each treatment at the three study sites (different letters indicate significant differences between treatments).

Response from the co-operating farmers was very positive. The Innisfail site was part of a Zero Tillage Producer Tour on July 20, 1993. Tour members were very interested in the outcome of our demonstration and the visual differences of the tillage treatments.

A complete economic analysis of the different tillage treatments is being determined. Although the yield is lower under no-till in the first year there are less input costs. There are less operations and less field work when compared to conventional methods. The final results will be valuable to farm managers interested in direct seeding of cereal crops into forage stands.

CONCLUSIONS

No-till seeding, as part of a pasture-cereal or hayland-cereal rotation, can eliminate tillage operations. By incorporating no-till seeding, the fields are less susceptible to wind and water erosion. There are less input costs and less time involved in seeding. However, the results from the 1993 crop year indicate that no-till grain yields tend to be lower than conventional tillage yields in the first year. However by the second year the no-till grain yields were comparable to conventional tillage methods. The results from this project will help to determine the economic feasibility.

The spread of yields between the fertilized and non-fertilized plots at Viking suggest that the amount of nitrogen fertilizer applied was not sufficient. In 1994, the plots were conducted with 5 different rates (0, 30, 60, 90, and 120 kg/ha) of nitrogen to determine the yield response to nitrogen. This helped determine that a higher rate of fertilizer could be applied in the first year. Then a more typical rate can be applied in the second year once the sod has undergone some decomposition.

Control of weeds and the forage grasses is very important. Spraying the grasses with ROUNDUP did control most of the growth of the forage grasses compared to the no herbicide treatment. However, there was still significant competition from the grasses in the no-till plots. The control plot emphasizes the need to suppress the forage stand using tillage and, or herbicides. It is virtually impossible for even a strong germinating crop such as barley to be able to survive.

Further investigation of seeding other crops into hay or pasture is needed. We will be researching the effects of no-till seeding of canola, peas, oats, and forages back into sod in 1995. We will also compare a disc drill to an airdrill and fall spraying versus spring spraying.

The results from this Farming for the Future Project will help in the evaluation of this cropping technology. The great cooperation of the farm managers on whose farms we are conducting research is greatly appreciated.

DIRECT SEEDING FIELD CROPS AND FORAGES INTO PASTURE SOD

Jeff Prochnau and Tom Jensen[1]

INTRODUCTION

The interest of direct seeding into sod has increased dramatically over the past two years. In 1993 we started a Farming For the Future "No-Till Seeding of Barley into Sod" project. Since then we have received numerous calls from farmers and district crop specialists wanting more information on seeding into sod. There is not only interest in seeding barley, but also increased interest in seeding cereals, oil seeds, pulses or forages into sod.

Intense tillage operations of ploughing, discing and cultivating are needed to break the sod. These tillage operations are costly and time demanding and they allow the fields to become susceptible to wind or water erosion. A method of using no tillage by direct seeding into a herbicide treated pasture sod would virtually eliminate soil erosion problems.

There have been recent advances in the design of direct seeding drills and airdrills. Examples are the John Deere (750 series), the Agri-systems Cross-Slot conservation tillage seed drill and the Harmon low-disturbance airdrill. These drills do an excellent job of placing seed and fertilizer into a sod field without pre-seeding tillage. They also lower the operation costs and virtually eliminate the risk of soil erosion.

To help develop information on this topic a research project titled "Direct Seeding Field Crops and Forages into Pasture Sod" was initiated by the Conservation and Development Branch of Alberta Agriculture Food and Rural Development in the fall of 1994. We will compare fall spraying and spring spraying of ROUNDUP to conventional methods. We will also compare canola, peas, oats, and a forage mixture to determine the potential for growing them when seeded into pasture sod.

METHODS

This experiment is at two sites: Warburg and at the University of Alberta Research Farm. A split-split plot design has been set up with 4 replicates and 3 main plots per replicate. Each main plot will be split by 4 crop species and further split using 2 different seed drills. Soil testing was carried out in the fall of 1994 to characterize each site and ensure proper nutrient requirements are supplied. The site at Warburg will be located on a pasture field and the Edmonton site will be located on hayland. The 3 main plot treatments to be investigated are:

1) <u>Ploughing</u> in early fall followed by 2 disc operations, one pass with cultivator and harrows, seeding and post emergent spraying for weeds as needed.

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2) Split Fall and Spring Applied ROUNDUP with 0.75 L/acre of ROUNDUP and 0.24 L/acre of 2-4D in early fall and 0.75 L/acre of ROUNDUP one week before seeding in the spring, no-till seeding, and post emergent spraying if needed.

3) Spring Applied ROUNDUP at a rate of 1 L/acre of ROUNDUP one week before seeding, no-till seeding, and post emergent spraying if needed.

The 4 crop species to be seeded are canola, peas, oats, and a forage mixture of alfalfa and timothy. We will also compare 2 different drills. In 1994 we had a small 8ft wide Harmon airdrill built and we will compare it with a John Deere 750 series disc drill.

The overall site area is 102m X 114m (1.2 ha or 2.9 acre). Main plots are 24m X 12m, further split into 6m X 12m crop species plots and 3m X 12m cropped seeddrill plots. A 12m border encircling each replicate will allow equipment turning. The border area will be seeded to a cover crop and mowed as required.

Some preliminary work on the project was completed in the fall of 1994. Plots were staked at both sites. On September 16th and 21st, plots were ploughed or fall sprayed with the mixture of ROUNDUP and 2-4D at Warburg and the Edmonton site respectively. On October 17th and 20th soil testing for nitrogen, phosphorous, potassium, and sulphur levels were measured and fertilizer will be applied as needed.

Care will be taken to ensure proper timing of the herbicide applications to achieve adequate control of weed species. ROUNDUP will be applied during the second week of May. Seeding will be carried out 7 to 10 days after the application of ROUNDUP. Post emergent herbicides will be used as required. Nitrogen fertilizer will be band placed at 80 lb/acre using the seed drill prior to seeding.

Data will be collected in order to determine the effects of the experimental treatments in three key areas.

1) Quality of the seed-bed. Measurements will include gravimetric soil moisture samples after seeding, soil temperatures at seed depth, the emergence of crop plants at one week intervals for 3 weeks and bulk density measurements.

2) Growth and yield of the crops. The forage plots will be harvested once in late July and total dry matter determined. The other crops will be harvested at maturity, with measurements of total dry matter yield of top growth, grain yield, and straw yield from yield samples. Throughout the growing season observations will be made biweekly to estimate dry matter yield and growth stage of the crops.

3) Weed Control. Weed numbers and types will be monitored and recorded.

4) Economic analysis of the 3 tillage systems and 4 crops. This will include input costs, gross revenues and net revenues. These will be determined on a cost per area basis.

All data from the experimental treatments will be compared using Analysis of Variance (ANOVA).

DISCUSSION AND PRELIMINARY CONCLUSIONS

In 1995, it will be the first year of the 2 year study. Preliminary field work was started in the fall of 1994. There was a good suppression of the grasses in the fall of 1994. when sprayed with 0.75L/acre of ROUNDUP and 0.24 L/acre of 2-4D. These plots will again be sprayed in the spring of 1995. Ploughing was also carried out in the fall of 1994. These plots will be disced in the spring of 1995.

Previous research indicates that a fall application may work better then just a spring application. This project will include a direct comparison of fall versus spring spraying.

In 1994 we used our Harmon airdrill to seed oats into a hayfield in the County of Lac Ste. Anne. The crop yield was respectable and averaged 81 bu/ac. The farmer felt it was as heavy as oats seeded conventionally in the area. With this project we will not only compare direct seeding to conventional seeding, but we will also compare the Harmon airdrill to our John Deere disc drill. We had success with both drills last year and now we will compare the two in a controlled factorial experiment.

A complete economic analysis of the different tillage treatments will be determined after 2 years of data are collected. These results will be valuable to farm managers interested in direct seeding into pasture sod.

Although this is the first year of the project there are some preliminary conclusions that were learned from other projects. Direct seeding, as part of a pasture-cereal or hayland-cereal rotation, can eliminate tillage operations. By incorporating direct seeding, the fields are less susceptible to wind and water erosion. We know that barley does work under direct seeding into sod. This project will investigate seeding other crops into hay or pasture.

Control of weeds and forage grasses is very important. Spraying the grasses with ROUNDUP does control some regrowth of the forage grasses. We will compare the effects of fall spraying to spring spraying. If no spraying is done it is virtually impossible for even a strong germinating crop such as barley to be able to emerge and produce a reasonable crop.

The results from this Conservation and Development Project will help in the evaluation of this cropping technology. The great cooperation of the farm managers on whose farms we are conducting the research is greatly appreciated. Monsanto Canada will also be involved and assisting in this project and we greatly appreciate their input.

BROADCAST OR BANDED UREA FOR DIRECT SEEDING

Jeff Prochnau and Tom Jensen[1]

INTRODUCTION

One of the important aspects of direct seeding management is how to apply nitrogen fertilizer. Early research into direct seeding was concerned with seeding equipment and nitrogen fertilizing was often limited to the use of broadcast applications of ammonium nitrate. Urea was a preferred source of nitrogen by many farmers because of the lower cost compared to ammonium nitrate. However surface broadcast applications of urea without any incorporation by tillage can result in significant losses of the nitrogen applied.

In 1995 the benefit of band placement of nitrogen under direct seeding is now generally accepted. This is especially true with the urea form of nitrogen fertilizer. There has been great emphasis on one-pass seeding in the spring time. All of the fertilizer is applied at the time of seeding. This one-pass seeding requires that producers handle all their fertilizer in the spring.

The industry partner of this project (Sherritt Fertilizer) is working on the development of a urease inhibiting coating for urea. This coated urea may make banding of urea under direct seeding less necessary when compared to broadcast applications.

Research comparing the uptake of both coated and non-coated urea is needed. The different application methods of surface broadcasting or banding will be compared. To help develop information on this topic a research project titled "Broadcast or Banded Urea for Direct Seeding" was initiated in the fall of 1994. The Conservation and Development Branch of Alberta Agriculture, Food and Rural Development started the project and received additional support from Sherritt Fertilizers.

METHODS

This experiment is at two sites: near Warburg on a Gray Luvisolic soil and at the University of Alberta Research Farm in Edmonton on a Black Chernozemic soil. A randomized complete block design will be used that includes 4 replicates or blocks. There will be 40 experimental treatments per block. It is proposed that research be conducted to compare, fall versus spring applications of both the coated and non-coated urea. There was an early fall application and late fall application. The early application at each site was the first week of October and the late application was the last week of October.

Additional experimental factors included, surface broadcasting with or without incorporation compared to band placement. A 40 kg/ha and 80 kg/ha of N level was included in the treatments.

In the spring of 1995 all spring fertilizer treatments will be applied. Soil moisture samples will be taken at 0.15m increments to a depth of 1.2m. Barley will be seeded on all of the plots when soil temperature is suitable. In crop spraying will be performed when the

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crop and weeds are at their appropriate leaf stage. Rain gauges will be used to measure precipitation throughout the growing season. Square meter samples of the barley crop will be harvested from each plot. Yields will be measured and ground plant samples analyzed to determine nitrogen uptake.

We had a small 2.5m (8 ft.) wide Harmon airdrill built the spring of 1994 that would be ideal for doing this type of research. The machine can be adjusted so that nitrogen can be placed in a band separate from the seed. This enables double shooting or one-pass seeding in the spring. The same machine can be used to band place nitrogen in the fall or spring, and then seed the crop in the spring. Additionally the air hoses can be removed from the opener shanks for surface broadcast applications. We used this airdrill for all fall applications.

The overall site area is 120m X 74m (0.9 ha or 2.2 acre). Each treatment plot is 2.5m wide X 6m long. There is a 10m border encircling the blocks to allow equipment turning. The border area will be seeded to a cover crop and mowed as required.

All data from the experimental treatments will be compared using ANOVA.

DISCUSSIONS AND PRELIMINARY CONCLUSIONS

In 1995, it will be the first year of the 2 year study. Field work started in the fall of 1994. Plots were flagged and as mentioned earlier, there was an early and a late fall fertilizer application. All work was done using our Harmon airdrill.

Previous research in the 1980's by Tom Jensen, in cooperation with Dr. Wayne Lindwall (Ag. Canada, Lethbridge) and Dr. Marvin Nyborg, (U of A) studied the efficiency use of two nitrogen fertilizers when broadcasted and banded. The fertilizers studied were N-15 enriched urea and ammonium nitrate applied at three sites in Southern Alberta seeded to barley. The study included both incorporation by tillage and no incorporation or direct seeded treatments. At a rate of 80 kg/ha of N, the urea resulted in a fertilizer use efficiency of 14% compared to 26 % for ammonium nitrate in the direct seeded treatments. Urea was approximately half as efficient as ammonium nitrate. Further work with wheat and the same forms of nitrogen either broadcasted or banded was done. There was a significant benefit to banding urea compared to broadcasting in all of the three site years of research. There was less benefit to banding ammonium nitrate when compared to broadcasting the same.

Additional research with fall versus spring applications of nitrogen fertilizer, banding versus surface broadcasting and incorporation versus no incorporation of the surface broadcast treatments, was also done. Generally banding was more efficient then broadcasting, and spring more efficient than fall applications. Fall banding even though less efficient than spring banding was more efficient than spring broadcasting.

We will determine whether the following methods of nitrogen fertilizer applications will result in crop (barley) yields similar to banding at the time of seeding:

- fall broadcasting of coated urea (coated with urease inhibitor)
- fall banding urea or coated urea
- spring broadcasting of coated urea

Some of the advantages of these alternate methods of fertilizer application are that fall applications can assist farmers in spreading out their annual work, and save time in the busy spring seeding period. Also the broadcast application of the coated urea will result in significant fuel or energy savings for the farmer. Placing fertilizer in the ground, below and to the side of the seedrow requires additional tractor power, fuel and machinery costs.

COMPARISON OF LEGUME BASED, CONTINUOUS CROPPING AND FALLOW ROTATIONS ON SOIL QUALITY AND PRODUCTIVITY

John Zylstra[1]

INTRODUCTION

This project is a cooperative one between Alberta Agriculture, Food and Rural Development and the Northern Alberta Research Center at Beaverlodge. The site is the Fairview Research Farm which is land donated by the M.D. of Fairview. This project was initially seeded in 1992 which became the establishment year for the project. It is intended to exist for at least three years.

Objectives

To compare five three year rotations. To evaluate changes in soil properties. To evaluate changes in N-fixing rhizobia populations.

METHODS

Plots were not cultivated the previous fall, and were cultivated twice in the spring before seeding with an eight foot wide double disc seed drill. 46-0-0 was broad cast before the second tillage operation. Plots were sprayed with appropriate herbicides and were harvested with a rotary thresh combine with a straight cut header and a chaff spreader on it in 1993 and swathed and combined in 1994.

Plots were seeded on May 15, 1993 and were harvested on September 28, 1993. In May/93, 11.5mm of rain fell, and in June 129mm of rain fell. An additional 21mm of rain fell by July 5, 1993.

In 1994, plots were seeded on May 10, swathed August 31 and harvested on September 22. In May, 8.5mm rain fell, in June 44.8mm rain fell, in July 106mm of rain fell, and in August 32mm of rain fell.

Wheat on wheat and canola stubble, and canola on wheat stubble received 130 lbs of 46-0-0 plus 50 lbs of 11-51-0. Wheat on peas received 80 lbs of 46-0-0 plus 50 lbs of 11-51-0. Wheat on green manure and on fallow received 50 lbs of 11-51-0 and 40 lbs of 46-0-0. Peas received only 50 lbs of 11-51-0. Seeding rates were 9kg/ha of canola, 90kg/ha of wheat, 9 kg/ha of red clover. Peas were targeted at 8 live seeds/sqft.

In 1994, wheat/canola on cereal/canola stubble received 94 lbs/ac N. Wheat on pea stubble received 37 lbs/ac N, and on fallow and green manure received 21 lbs/ac N.

RESULTS

In 1992 the first replication had the highest yields as that rep had the most moisture reserves. In 1993, there was more opportune moisture and rep one had lower yields than reps 2 and 3. Yields were less variable in 1993 than in 1992. In 1992, peas removed the most nitrogen, phosphorus and potassium, and canola removed the least nutrients based on yields.

In 1994, wheat did not receive the benefit from the higher amounts of N added, and yields were reduced due to less favorable moisture than 1993. Peas still performed quite well.

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Treatment	1992	1993	1994
	Bushels per acre		
Wheat on oat greenfeed	34		
Wheat on wheat		52	25
Wheat on peas		56	29
Wheat on canola		59	29
Wheat on green manure		40	32
Wheat on fallow		69	30
Canola on oat greenfeed	15		
Canola on wheat		39	20
Peas on oat green feed	38		
Peas on wheat		53	45

PRELIMINARY CONCLUSIONS

Results will be analyzed more completely in 1995. Results will also be compared and combined with two additional sites at Beaverlodge and Ft. Vermilion under the management of George Clayton with the Northern Alberta Research Center. 1995 yields will be the first after a complete 3 year cycle.

CONSERVATION - WATER MANAGEMENT

A METHOD FOR MODELLING ALBERTA SOIL MOISTURE CONDITIONS

A. Howard[1] and J. Kirtz[2]

INTRODUCTION

Soil moisture maps for dryland stubble fields have been produced annually since 1982 for the fall, and since 1988 for spring. The maps are based on determination of soil moisture from samples taken across the province during October and April. The maps have served as an important tool for the prediction of crop performance and determining the potential for drought in the province. In keeping with Branch objectives, however, monitoring of soil moisture levels will be based primarily on modelling and the emphasis on sampling is to be reduced. A model for tracking growing season moisture conditions in near real-time has been developed and is currently being tested against existing soil moisture maps. This report presents the initial results of the tests of the model against the field-based maps for the 1993 and 1994 seasons.

METHODS

Components of a prairie-wide model used by the Winnipeg Climate Centre (WCC) (Raddatz, 1989) were acquired by the Conservation and Development Branch. The WCC model was based on the approach of Dunlop and Shaykewich (1982) who applied concepts similar to those in the Versatile Soil Moisture Budget (Baier et al. 1979). The approach used daily temperature and precipitation data from a given site along with non-daily (input once per year) soils, crop and location information from the site to calculate several agrometeorological products including soil moisture.

The model was rewritten during 1993-94 to streamline input procedures and modified to utilize the detailed information available for crops and soils in Alberta. The modifications were expected to improve the resolution of the model, increasing spatial accuracy when predicting conditions across the province. The modifications were primarily aimed at utilizing the spatially-dependent data available on soils, planting dates, initial soil moisture conditions, and climate. Use of crop distribution data is planned for a future modification once the existing model has been tested and proven satisfactory.

Soil variability in the form of water supply capacity information from Tajek et al. (1989) was input as the Water Holding Capacity (WHC) variable. Data extracted

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[2] Snowy Owl Software, 20 Ross Drive, Ft. Saskatchewan, Alberta

from the spring soil moisture map replaced the Initial Soil Moisture variable. Planting date data was obtained from Alberta Agriculture, Food & Rural Development District Offices, and from agribusiness communications. Climate data came in two sets, a near real-time set of 89 stations used during the 1994 test, and an archived set from which 182 stations were chosen to test the 1993 season. Climate data sources included Environment Canada (through the AAFRD Agriculture Weather Summary database), Alberta Environmental Protection, Agriculture and Agri-Food Canada Research Stations at Lethbridge and Beaverlodge, and the AAFRD Irrigation Branch.

The township was chosen as the basic unit of calculation, and therefore all data required conversion to a township scale, regardless of what scale it was originally obtained at. Soil WHC data was available at ¼ twp scale and was therefore grouped to arrive at the township scale. Planting date data was assigned to the townships within the corresponding crop districts. Climate data were point data that was assigned to areas determined mathematically, based on the Theissen polygon approach. These climate areas varied from less than 5 to over 100 townships in size, depending on the density of climate stations. Conversion of the data to township scale was performed by subroutines in the model. During a run, the model calculated daily soil moisture for every township in the agricultural zone of Alberta.

During 1994, the model was tested for the ability to generate near real-time soil moisture and crop conditions during the growing season. In addition, yearly output for Oct 31, 1994 was tested against the 1994 fall soil moisture maps. The model was also run using inputs for the 1993 year and the output for Oct 31, 1993 was compared against the 1993 fall soil moisture map. Analysis is continuing for 1991 and 1992.

RESULTS

__Near Real-time Operation (1994)__:

Programming was completed during April of 1994, and the model generated bi-weekly soil moisture update maps from June to early August. Changes in Environment Canada's distribution of climate information resulted in significant delays in obtaining data during August and September. As a result no near real-time maps were generated until the data availability improved in October. When data availability was normal, update maps could be generated within three days of real time and within 1½ days of receiving the data.

Seasonal update maps of soil moisture and crop growth stages were circulated to field staff, and feedback indicated that the model generally assessed crop conditions well, except for the northern Peace River region. In this area the model predicted growth stages that were ahead of field conditions by almost two weeks as the crop approached maturity. Soil moisture conditions generally matched those reported in the field.

__Comparison Against Field Based Soil Moisture Maps__:

The growing seasons of 1993 and 1994 represent a contrast in climatic conditions. The 1993 season was cool and wet, with crops in many areas failing to

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A. Howard[1] and J. Kirtz[2]

INTRODUCTION

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The model was rewritten during 1993-94 to streamline input procedures and modified to utilize the detailed information available for crops and soils in Alberta. The modifications were expected to improve the resolution of the model, increasing spatial accuracy when predicting conditions across the province. The modifications were primarily aimed at utilizing the spatially-dependent data available on soils, planting dates, initial soil moisture conditions, and climate. Use of crop distribution data is planned for a future modification once the existing model has been tested and proven satisfactory.

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CONCLUSIONS

The model is expected to quantitatively assess provincial soil moisture conditions during the growing season and predict the distribution of soil moisture conditions during the fall, ultimately eliminating the need for a field based map. Operation is fast enough to provide near real time products, however, production is highly dependent on the availability of data from other agencies. Delays or failure to provide data is reflected immediately in production.

Comparison to field maps is a comparison of two approaches, each using assumptions to handle the complex situations that arise from soil, crop and climate variability. Early indications suggest that while the approaches tend to converge toward similar provincial patterns during drier years, they do not converge during wetter years. Until more is understood about the how range of field conditions affect calculated output from the model, care must be taken when interpreting model based maps.

ACKNOWLEDGEMENT

The authors would like to thank Rick Raddatz of the Winnipeg Climate Centre for providing the model upon which the project was developed, and to Joe Tajek of Agriculture and Agri-Food Canada, Alberta Soil Survey for providing the water supply capacity information used in the project. Appreciation is extended to the Alberta Pool and also to the previously mentioned agencies who contributed the climate data. Special thanks is extended to Peter Dzikowski, Agricultural Weather Resource Specialist, Alberta Agriculture, Food and Rural Development for his input and review.

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EFFECT OF STUBBLE HEIGHT ON MOISTURE CONSERVATION, SOIL TEMPERATURE & YIELD

FFF Project No. 930318

A. Howard[1], J. Michielsen, D. Sliworski [2], and G. Peers[3]

INTRODUCTION

As a result of the persistent drought during the 1980's, there has been considerable interest in ways to conserve dryland soil moisture in the MD of Acadia. A project was initiated in 1993 to compare three practical ways of using stubble to trap snow by monitoring their impact on spring soil moisture and temperature, crop performance and economic feasibility. This report is an update of activities and results in year two of an eight year study.

METHODS

Site Description

A site was selected at NE 16-24-2-W4, six miles south of Acadia Valley (Figure 1). Preliminary sampling was completed in May 1993, immediately after seeding. The field was level and in a spring wheat/fallow rotation with a strip cropping pattern. The soils were classified as Orthic Brown Chernozems developed in lacustrine material, based on visual examination of the soil profile and comparison to the criteria identified in the Canadian System of Soil Classification (Agriculture Canada, 1987). Two strips, identified as strips A, seeded to spring wheat, and B, in fallow during 1993, were chosen for the study. Clay content within the strips ranged from 51% to 64% at the surface, and increased below 60 cm depth. Areas that showed evidence of ponding or runoff were excluded from the study. No accumulations of salinity or sodicity were evident on the site.

The three stubble conditions include stubble from swathing (short stubble), stubble from direct combining (tall stubble), and trap strips of tall and short stubble (alternate height stubble). The project design provided for 12 plots (4 reps x 3 treatments) in the stubble strip and 12 additional plots in a nearby chemfallow strip. By utilizing two sets of plots, data pertaining to moisture, temperature, crop growth and yield can be obtained on a yearly basis.

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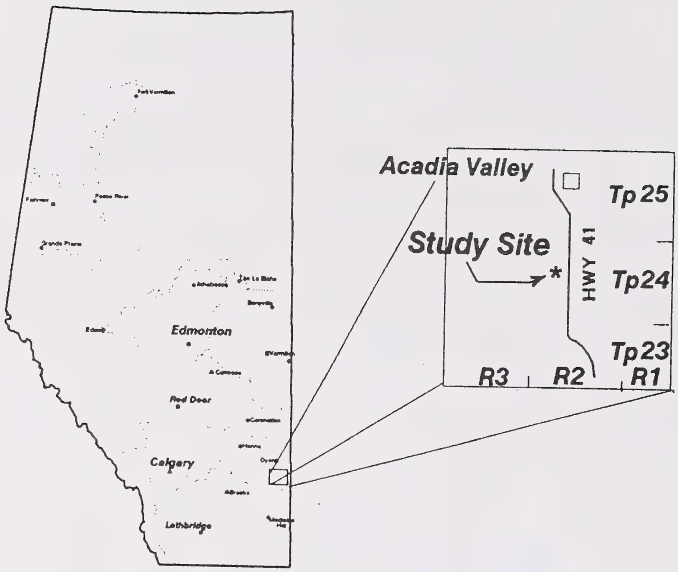


Figure 1. Location of study area

Progress

Plots were instrumented in Strip A (chemfallowed in 1994) during October 1993, and snowdepth, snow density, soil moisture, and soil temperature were monitored during the winter and spring. Soil moisture was determined by gravimetric analysis during October 1993 and May 1994, prior to seeding. Surface soil moisture (0-15cm depth) was measured in detail across the plots at the 0-15 cm depth using a Time Domain Reflectometry (TDR) device. Soil temperature was monitored continuously at one replicate of each treatment using a datalogger. Air temperature and precipitation (rain and snow) were measured continuously at the site since the winter of 1993.

During September 1994, plots were established in Strip B (cropped during 1994). The plots were instrumented and sampled in the same manner as the first strip. All plots were combined in a single operation, leaving tall stubble (70cm height) on the entire strip. The short (conventional) and the alternate height plots were cut later, the short stubble to 25cm height. The alternate height plots were made by cutting 40cm high strips into the tall stubble. Fall soil moisture was determined by sampling at depths of 0-10, 10-20, 20-30, 30-40, 40-60, 60-80, and 80-100 cm depths and performing gravimetric analysis. On this strip TDR, neutron probe, and soil temperature monitoring were not conducted since it will go into fallow during 1995.

Resources were focused on Strip A this fall, with nine CR-10 dataloggers installed, allowing continuous soil temperature monitoring at three replicates of each treatment. Sampling for gravimetric soil moisture measurements was completed, and surface soil

allowing continuous soil temperature monitoring at three replicates of each treatment. Sampling for gravimetric soil moisture measurements was completed, and surface soil moisture measurements using TDR were taken prior to freeze-up. Snow precipitation was measured this winter as in the past, using a nipher collector gauge. Snow accumulation measurements were planned for this winter, however none have been taken since there has been virtually no snow accumulation at the site.

During 1995, soil nutrient levels will be determined prior to seeding in strip A. Costs and economic returns will be recorded and used in determining the economic benefit of each treatment.

RESULTS

Snow Precipitation and Accumulation

Weather conditions during 1993 and 1994 represent a high degree of contrast. The fall 1993 resulted in wet field conditions and the winter produced ample snowcover until mid-March, when a major melting period occurred. The ground was thawed by early April. Spring 1994 was warmer and considerably drier than normal.

Fall 1994 resulted in generally dry field conditions for the cropped 1994 site and snowcover to date has been sparse or nonexistent. Precipitation in the area since November 1 has been 44% of normal.

During the winter of 1993-94 a permanent snowcover began in early November, and reached maximum accumulation by early February, completely filling the short stubble plots. The short stubble plots had the shallowest depth of snow cover and lowest water equivalent (Table 1). The alternate height treatment had similar average snow depths to the tall stubble but it had the highest average water equivalent. The tall stubble had the lowest snow density, which reduced the water equivalent of the snow cover.

The snow densities are consistent with central Montana data for a relatively "fresh" snowpack (Caprio et al., 1986). The central Montana data also showed that the average snow density in tall stubble fields tended to be lower than that of short stubble fields in areas subjected to a high frequency of chinooks. During Montana winters, the tall stubble consistently retained deeper snowcovers and higher water equivalents than the short stubble.

Soil Moisture

Overwinter soil moisture gains are presented in Table 2. Even though fall soil moisture conditions were wet, two treatments averaged over one inch of moisture gain. Lowest gains were observed in the alternate height stubble plots, whereas similar gains were observed in the tall and short stubble plots. Statistical analysis using ANOVA and Duncan's Multiple Range test showed that the differences in the top 60cm between the alternate height and the other stubble treatments were significant at the 5% level, rejecting the null hypothesis for this year's data. The differences in moisture gain in the 0 - 100cm depth were not statistically significant.

Table 1. Snow precipitation and accumulation averages for the tall stubble, short stubble and alternate height stubble at Acadia Valley, February 1994

	TALL	SHORT	ALTERNATE HEIGHT[1]
WATER EQUIVALENT (mm)	53.37	30.94	62.46
SNOW DEPTH (cm)	29.77	14.76	29.43
DENSITY[2] (gm/cm^3)	.179	.210	.212
PRECIPITATION (Nov/93-Jan/94)	52.8 mm		

[1] Represents average of short and tall strips. [2] 1 g/cm^3 = 10 mm water/cm snow

Larger gains had been expected in the alternate height stubble plots. Because surface conditions were moist at freeze-up, the potential for frost seal, and consequently runoff, was high. The TDR data was unable to show any clear patterns in moisture distribution in the alternate height stubble that would explain the lower moisture gains. Additional measurements sites within the alternate height plots have been added for 1994-94.

Table 2. Data summary for total soil moisture in the top metre at the Acadia Valley plots

		TALL	SHORT	ALTERNATE HEIGHT
MEAN FALL SOIL MOISTURE (mm/m)		370	348	370
OVERWINTER GAIN (mm)	0-30	9.9a	10.6a	4.0b
	0-60	22.4a	23.2a	7.4b
	0-100	28.7a	31.7a	15.5a

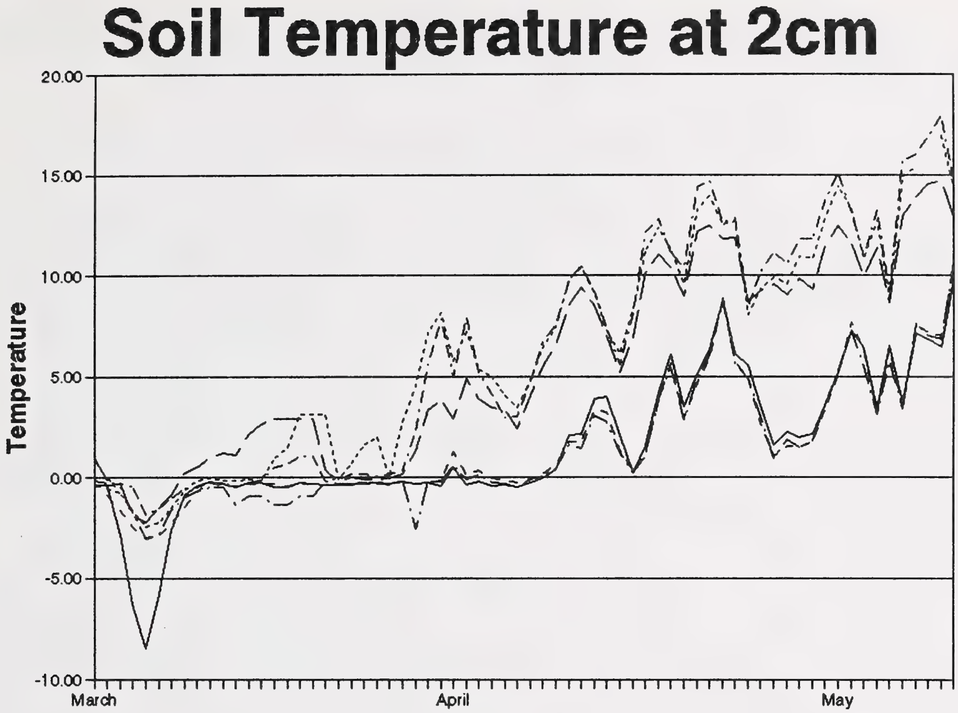
* different letters indicate significance at 5% level (Duncan's Multiple Range Test)

Soil Temperature

The unusually warm weather during March and April provided an environment for rapid soil warming. Soil temperature monitoring data was analyzed from March 4 through May 10. Mean daily temperature data showed no significant difference between treatments during any part of the monitoring period.

Mean temperatures, presented in Figure 2, averaged -3°C on at 2cm and 5cm depths on March 4, and the soil warmed at an average of 0.2°C per day at these depths. The mean soil temperature reached 5°C (seeding temperature) on April 10, however it dropped below again April 13. On April 16 the mean temperature warmed back up to 5°C and remained above for the remainder of the monitoring period.

A strong cooling period during early March produced cold air temperatures, which reached a minimum of -18°C on March 8. During the cold period, the short stubble



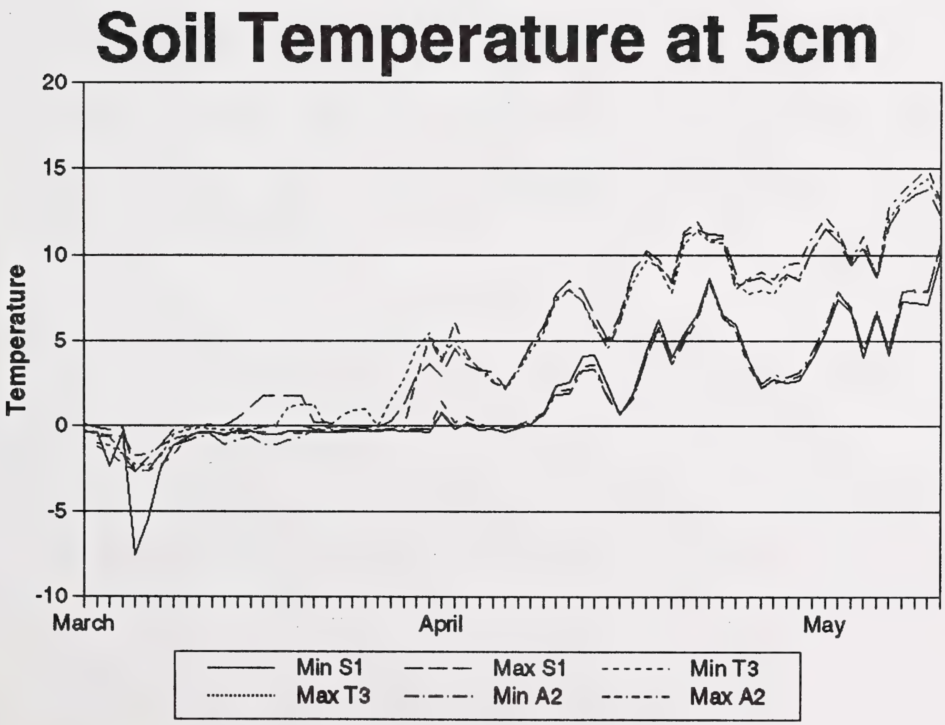


Figure 2 Daily maximum & minimum soil temperatures at seeding depth for the short stubble (S1) stubble (T3) and alternate height stubble (A2) during Spring 1994.

treatment showed a corresponding sharp drop in soil temperatures that was not observed in the tall or alternate height treatments.

CONCLUSIONS

The preliminary snow accumulation data show that alternate height stubble has a higher potential for holding snow and water than tall stubble, however this was not reflected in overwinter moisture gains. The wet conditions from the fall of 1993 may have been a factor in the lower recharge rates in this treatment.

The first data that relates stubble height to seedbed conditions and crop growth will be available in 1995, which is the first time the field will be seeded under the stubble treatments. Soil moisture levels in this field are high, although the surface is drying from the warm winter weather and lack of snowcover. The conbination of at wet field going into fallow, followed by a dry winter may show how the stubble treatments affect evaporation and protect seedbed moisture.

ACKNOWLEDGEMENT

Appreciation is extended to AARI who helped support this project through a Farming for the Future research grant. The authors also wish to thank Germar Lohstraeter for his work in obtaining TDR measurements at the site.

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INFILTRATION UNDER VARIOUS CROPPING SYSTEMS

K. Skarberg and T. Goddard[1]

INTRODUCTION

Soil moisture storage and retention is important when one is trying to maintain a cropping system. Alberta has a moisture deficit during the growing season so any management practice that will increase infiltration or moisture storage is desirable. Research has shown that cropping systems have a considerable influence on infiltration capacity. Naeth et al. (1991) found that infiltration capacity and storage potential on rangelands increased with better vegetative growth, decreased soil compaction and less exposed soil. Nolan and Goddard (1992) found that infiltration capacity was higher under zero till versus conventional till systems.

The rainfall simulator and Guelph double ring infiltrometer are two methods of measuring infiltration. The rainfall simulator imitates the impact of raindrops falling on exposed ground which can cause soil particle detachment and surface sealing, reducing infiltration. The double ring infiltrometer is a flooding method. The soil surface is covered by a certain depth of water which is kept constant and the amount of water used to keep the water depth constant and time it takes to infiltrate being measured.

The simulator imparts kinetic energy and allows measurement of the dynamics of infiltration where the double ring infiltrometer does not. The surface area involved in infiltration measurements with the rainfall simulator is about 6.5 times larger than that measured by the double ring infiltrometer. This is important when one is trying to measure infiltration on an undisturbed site (soil cracking, plants, etc). The simulator allows measurement of a larger and therefore more heterogeneous area and repeated measurements proved more consistent than those of the double ring infiltrometer (Gupta, 1993).

The objective of this study was to assess infiltration as influenced by two cropping systems using two methods of measurement - the rainfall simulator and the double ring infiltrometer.

METHODS

The study location was the site of a five year project comparing continuous cropping of cereals and oilseeds with continuous forages. The project is being conducted by the Battle River Research Group and is located east of Camrose, near Ohaton. The landscape is level to undulating with Camrose Loam being the dominant soil type. It is a solodized solonetzic soil developed on glacial till. The Camrose Loam soil is generally poor to fairly good in drainage and is characterized by a relatively loose, black surface horizon, a very hard columnar subsurface and a salt concentration in the subsoil. This soil is subject to wind erosion due to the loose topsoil and water erosion due to the very hard subsurface which

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impedes infiltration and root penetration. (Soil Survey of the Peace Hills Sheet, 1947).

In 1989 the whole field was cropped to a cereal and the stubble was left standing after harvest. The following year one half of the field was cropped to canola and the other half to canola underseeded to alfalfa. Since that time the straight canola field has been continuously cropped to either cereals or oilseeds. The canola field that was underseeded to alfalfa has been left in alfalfa since 1990. The rainfall simulator was used at the end of the fourth year of the project to assess infiltration under different cropping practices.

Rainfall Simulator Method

The sites within the field selected for simulator runs were picked on the basis of available slope. Most of the field had low slopes (< 4%); maximum slopes (> 4-6 %) were only found on a small portion of the field. Slopes within the simulator plots ranged from 4-6%, with an average of 5% (measured with an Abney level).

A rainfall simulator was used to imitate rainfall activity and measure infiltration under the different cropping practices. The simulator is a tripod with a single, solid cone sprayer nozzle and a pressure gauge which when connected to a water and power source can deliver water under pressure at varying intensities. It is based upon the Guelph Rainfall Simulator (GRS) II design as described by Tossell et al. (1987) with modifications (Nolan and Goddard (1992).

The simulator was set up over a 1 m^2 bounded plot within the study area and a constant rate of water was applied at a target intensity of 140 mm/h (5.5 in./h). Rain gauges were placed on 3 sides of the microplot to measure the actual intensity. Four repetitions were done on both the canola and forage treatment areas. Simulation duration was 25 minutes for all of the simulator runs. All runoff from each plot was collected to determine total runoff. Soil loss and runoff rates were determined by collecting runoff subsamples every three minutes for a one minute duration. Infiltration rate was calculated by difference between runoff rate and actual applied rate of water. An analysis of variance (ANOVA) using the Student Newman Keuls test at a probability level of 0.05 was used to test for difference between the treatments.

Double Ring Infiltrometer Method

A double ring infiltrometer from Agriculture and Agri-Food Canada (CLBBR, Edmonton) was used to compare infiltration measurements against the rainfall simulator for the same treatments. The double ring infiltrometer is a calibrated plastic cylinder which is held up by a rod and clamp system and surrounded by two metal rings. The rings are driven into the ground with the central ring driven in 1-2 cm deeper than the buffer ring. The buffering ring and deeper depth to which the central ring is driven is to reduce the possibility of lateral flow. The rod and clamp system is anchored on the outside edge of the central ring and the cylinder is suspended by the clamp inside the central ring at a height equal to the pressure head in the top of the cylinder. The rings are then filled to an equal depth with water so that the water in the central ring just touches the bottom of the cylinder. Valves on the cylinder are opened to allow water to drain into the central ring and maintain a constant head as the initial volume of water infiltrates. The rate at which the water in the cylinder drops is recorded and represents infiltration rate under a constant and equal head.

Measurements are taken until a steady-state infiltration rate is reached (three measurements in a row are the same).

The double ring infiltrometer was ran three times on the canola treatment and twice on the forages treatment. Measurement duration ranged from 48 to 67 minutes on the two treatments.

Soil Sampling and Analysis

Soil moisture and texture samples were taken prior to the rainfall simulator and double ring infiltration measurements. A core, 6 cm deep was removed from the surface (Ap) soil outside of each plot. Soil moisture and bulk density were determined gravimetrically. Bulk samples of the same horizon were used to determine soil organic matter and texture. Two soil pits were dug to obtain soil profile information.

All plots (simulator and infiltrometer) were hand clipped to ground level. As much residue as possible was removed by hand, without disturbing the soil surface. This was to present a bare surface at all runs and reduce raindrop impact interception. Thus, differences in infiltration should be due more to soil surface characteristics than residue amounts. Remaining residue was measured with a measuring tape using the line-transect method (Sloneker, 1977). Residue occurrence (canola hull size or larger, including stones) was counted at decimeter intervals on two diagonals of each simulator plot to obtain a percent residue cover.

Surface roughness was measured using a 1 m board placed across the plot at a position 1/3 and 2/3 up from the bottom of the plot. Measurements were taken along the board as the distance from the bottom of the board to ground level (Δh). Proportion of the 1 m distance at different Δh classes was visually estimated.

RESULTS

Soils

Two soil pits were dug to obtain soil profile information. One pit was located between two of the canola simulator plots and the other closer to the canola/forage border. The A horizons of both pits were of loam texture and medium to fine granular in structure becoming more dense and of a weak subangular blocky structure as one went deeper. In Pit #1 the deepest horizon reached was of a firm clay texture with carbonate concretions and a strong HCl reaction whereas this type of horizon was not reached in Pit #2. Visual assessment indicated no solonetzic properties in either profile although evidence could be seen in the field. It appears that solonetzic properties in the field are in a degraded form, consistent with the soil survey, and topsoil depths are deep for the area.

Soil samples were analyzed for soil moisture, bulk density, texture and percent organic matter. Surface ground cover was measured after standing residue had been clipped and removed. Soil moisture and silt content were found to be statistically higher on the canola treatment, while bulk density was statistically higher on the forage treatment. The remainder of the soil properties were found to be not significantly different at an SNK test probability level of 0.05.

Residue cover on the canola treatment was 1.7 times less than on the forage treatment and was statistically lower. Even though every effort was made to remove residue, upon final inspection it was found that a lot of the fines (broken canola hulls, alfalfa leaf pieces) had been left in small depressions, crevices, etc. Additional effort to remove them would have damaged the soil surface and affected infiltration rates even more.

On the canola plots, surface roughness was found to be more defined, the furrows developed a system of continuous waves, while it was smoother and more variable on the forage plots. The furrows within the canola treatment were all 3-4 cm in depth. A large proportion of each 1 m measurement taken across each forage plot had furrows less than 1 cm in depth, with a small proportion of the furrows 3 to < 4 cm in depth.

Rainfall Simulator Infiltration

Using the difference between the actual intensity rate for each simulation and the runoff rate for each collected subsample, infiltration rate curves were created for each simulator run (Figure 1). The canola treatments had an average initial infiltration rate of 92 mm/h and a final infiltration rate of 88 mm/h, while the forage treatment had an average initial infiltration rate of 95 mm/h and a final rate of 71 mm/h (Table 1). Initial infiltration rate for the simulator runs was the actual average rainfall intensity for the simulation, final infiltration rate was the infiltration rate at the 24 minute subsample. Rainfall was shut off at 25 minutes for all simulations. The variation in final infiltration rates between simulations on the canola treatment was only 4.3% whereas on the forage treatment variation between simulations was 16.8%, almost 4 times more variation than on the canola treatment.

Table 1. Measured Rainfall Simulator Properties

Run Id	Treatment	Actual Intensity (mm/h)	Total Soil Loss (g)	Total Runoff (L)	Initial Infiltration (mm/h)	Final Infiltration (mm/h)
3001	Canola	89.65	7.54	1.63	89.65	85.07
3002	Canola	88.12	7.66	1.38	88.12	84.90
3003	Canola	94.16	4.74	0.34	94.16	93.06
3004	Canola	95.19	3.75	1.45	95.19	88.90
Mean		91.78 a	5.92 a	1.20 b	91.78 a	87.98 a
SD		3.42	1.98	0.58	3.42	3.86
3011	Forage	100.18	31.70	10.62	100.18	73.12
3012	Forage	98.54	7.25	4.10	98.54	86.85
3013	Forage	89.17	12.59	9.52	89.17	62.16
3014	Forage	93.56	6.55	9.41	93.56	61.41
Mean		95.36 a	14.52 a	8.41 a	95.36 a	70.89 b
SD		5.00	11.77	2.93	5.00	11.91

(Values followed by the same letter within a column are not significantly different using an SNK test at a significance level of 0.05)

Double Ring Infiltrometer Infiltration

The double ring infiltrometer followed the same general trend in terms of final infiltration as the rainfall simulator. Final infiltration on the canola was higher than on the forage treatment (Table 2).

Table 2. Double Ring Infiltrometer Measurements

Treatment	Average Initial Infiltration (mm/h)	Average Final Infiltration (mm/h)	Average 24 Minute Infiltration (mm/h)
Canola	630	54	76
Forage	129	37	66

Three repetitions on the canola treatment using the double ring infiltrometer resulted in an average initial infiltration of 630 mm/h and average final infiltration was 54 mm/h. Initial infiltration for the double ring infiltrometer was the rate of infiltration after 1 minute, final infiltration rate was an average of the last 3 infiltrometer readings. End times for the infiltrometer varied from 45 - 67 minutes. On the forage treatment, average initial infiltration was considerably lower than on the canola treatment (129 mm/h) and a final average infiltration rate of 37 mm/h. Figure 2 illustrates the infiltrometer repetitions on each of the treatments.

To compare the simulator and infiltrometer it is useful to look at both at a common end time. The last infiltration rate measurement for all rainfall simulations was at 24 minutes, thus infiltrometer rates at the 24 minute mark were taken from the data for comparison. The average 24 minute infiltration rates for the canola and forage treatments using the double ring infiltrometer were 76 mm/h and 66 mm/h respectively. As with the final infiltration rates for the simulator, infiltrometer infiltration was greater on the canola treatment compared to the forage treatment. Variation in runs within a treatment using the double ring infiltrometer ranged from 21% for the canola to 1.5% on the forage treatment at the 24 minute mark. Variation in the canola treatment at the 24 minute mark was 14 times greater than at the corresponding time in the forage treatment.

DISCUSSION

The use of the rainfall simulator and double ring infiltrometer to measure infiltration on a field comparing continuous cropping to continual forages showed higher final infiltration on the canola treatment than on the forage treatment. The canola infiltration rate was 23% greater than the forage infiltration as measured by the rainfall simulator and 15% greater when measured with the double ring.

Infiltration was statistically higher on the canola treatment than on the forage treatment. Bulk density was statistically higher on the forage treatment than on the canola treatment. The higher bulk density on the forage treatment meant there was less water storage capacity and drainage space. Therefore infiltration was slower even though soil moisture was lower on the forage.

Residue cover influences infiltration rates. Residue acts to slow runoff down, cause ponding and decrease soil loss. Both treatments in this study had residue levels above 40 %. Residue cover was higher on the forage treatment than the canola treatment, but in both cases much of the residue was either consolidated or anchored. Even though as much residue as possible was removed prior to the rainfall simulations the amounts of fine residue (broken canola hulls, alfalfa leaf pieces) left may have influenced infiltration by presenting small

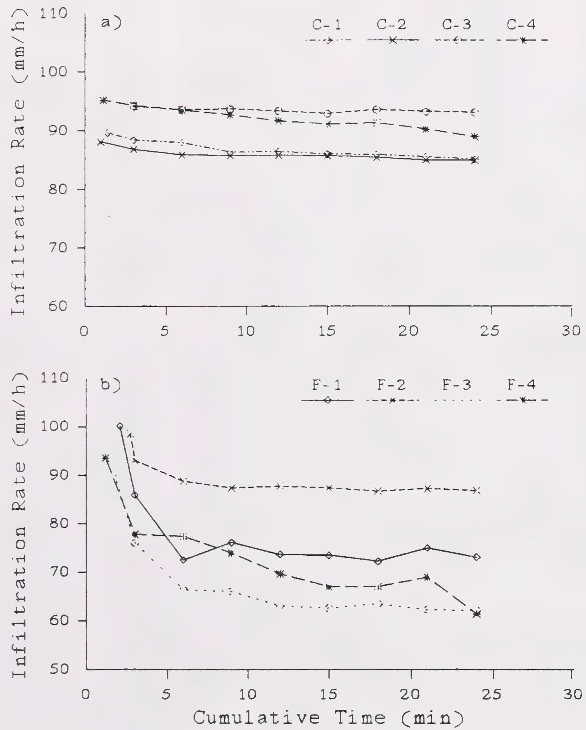

Figure 1. Infiltration rate curves from the rainfall simulator on the canola (a) and forage (b) treatments.

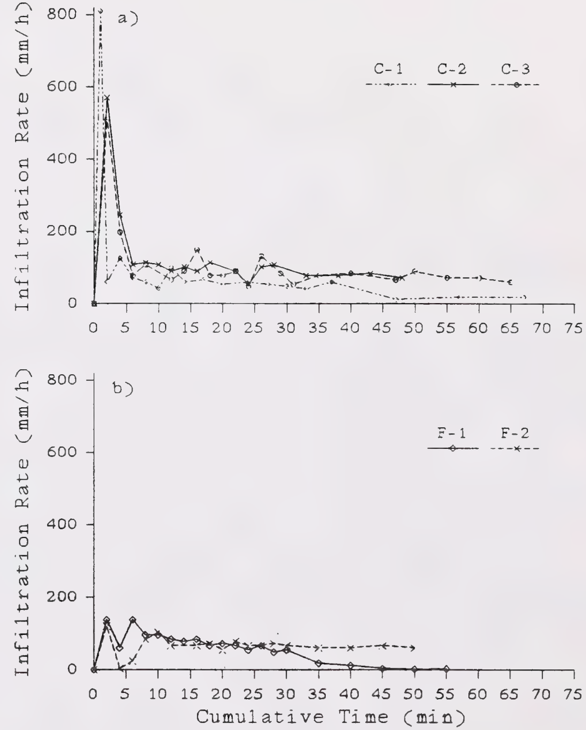

Figure 2. Infiltration rate curves from the double ring infiltrometer on the canola (a) and forage (b) treatments.

dams to hold water back and allow more time for infiltration. It may also have reduced soil loss by protecting the surface from the impact energy of raindrops. The statistically higher levels of residue on the forage treatment influenced soil loss and infiltration. The forage treatment had a much smoother surface than the canola, with only plant crowns to block runoff and soil loss. Soil loss was 2.4 times higher on the forage treatment but was not statistically higher than soil loss from the canola. The high levels of residue would have slowed the rate of runoff so that not as much sediment could be carried off the plot but rather, be trapped by the residue. The smooth surface however, allowed runoff to divide and flow around the plant crowns, decreasing the occurrence of ponding and hence infiltration. The canola treatment in contrast, had lower residue cover but a more stable and complex surface, reducing the soil loss and increasing infiltration.

The canola field is worked every year in preparation for seeding resulting in the creation of prominent furrows. The canola treatment had defined surface drainage paths (5 troughs) within the simulator plot borders. Clods or clumps of residue sometimes occurred in the channel bottoms. These would act as miniature dams to decrease flow from the plot, increase surface storage and allow more time for the water to infiltrate.

The forage treatment has not undergone any cultivation in 4 years, but travel across it with swathers, balers, bale haulers and plant crown disturbance has broken down the furrows that may have existed in the initial year of seeding (1990). Much of the surface roughness on the generally flat forage plots is due to plant crowns, and a small amount of residue ridges. The forage surface only has plant crowns acting as a flow barrier as the surface was generally smooth, overall. This lack of flow path complexity contributed to lower infiltration as dams were not formed.

The area exposed to the ring infiltrometer flooding is much smaller than in the simulator plots, however, the microsurface still influences infiltration. Because the infiltrometer is more of a flooding method, residue forming dams is not really a factor, but the plant composition may be. In the canola treatment, canola stalks were the only type of anchored residue to deal with. The macrostructure created by the furrows and plant stalks within the canola infiltrometer area influenced infiltration. In the forage treatment, the type of plant crowns varied due to the forage treatment being a mix of alfalfa and grasses. Plant species present within the infiltrometer surface area varied between runs which may have contributed to the variability between runs. Different plants change the microsurface as well as the macro- and micro- structure of the soil, affecting infiltration.

A final limiting factor of infiltration is slope. The greater the slope, the more rapid the runoff and less the infiltration. The less the slope, the more ponding, surface storage, and time for infiltration. In addition, ponded water protects the soil surface from additional waterdrop impact so soil detachment and erosion is reduced. At lower slopes the characteristics of measuring infiltration become similar regardless of whether the rainfall simulator or double ring infiltrometer tool is chosen.

CONCLUSION

An infiltration study was conducted in September of 1994 on a research field comparing two cropping systems - continuous cropping versus continual forages. Both field

plots were initiated in 1989 and in 1990 the one half of the field was cropped to forages and the other has been continuously cropped cereals and oilseeds. Two methods of infiltration measurement were used, the rainfall simulator and the double ring infiltrometer. Both forms of measurement showed higher infiltration on the continuously cropped area (by about 20 %) than on the forages treatment area. The rainfall simulator gave higher infiltration measurements on both treatments (continuously cropped versus forages) than the double ring infiltrometer. Bulk density, residue cover and microtopography of the test area all influenced infiltration. The larger area used in rainfall simulator measurements may account for some of the difference in infiltration rates between the simulator and infiltrometer measurements. The possibility exists that once the forages are cultivated and all the surface residue material is incorporated that infiltration rates by treatment may reverse. As it stands now, the statistically higher bulk density on the forage treatment seems to be the limiting factor influencing infiltration in this comparison of cropping systems.

A more detailed report on the findings of this study entitled 'Infiltration as Influenced by Cropping Systems' is available from the Battle River Research Group.

ACKNOWLEDGEMENTS

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CONSERVATION - DRYLAND SALINITY

TRACE ELEMENT CONTENT OF SOIL SATURATION EXTRACTS ASSOCIATED WITH SALINE SITES IN SOUTHERN ALBERTA

J.J. Miller[1], B.J. Read[2], D.J. Wentz[2], and D.J. Heaney[3]

INTRODUCTION

High concentrations of trace elements in soils may pose a threat to agricultural production. Accumulations in plants to phytotoxic levels adversely affects the health of humans and animals that consume these plants. Leaching of the trace elements into the groundwater degrades the water (Deverel and Fujii 1990). Dryland soil salinity is a serious concern in southern Alberta with approximately 0.65 million ha affected (Sommerfeldt et al. 1984). High concentrations of trace elements such as B and Se can occur in saline soils, and can be affected by the same processes that affect soil salinity (Deverel and Fujii 1990). A survey of the total trace element content of saline surface soils and salt efflorescence in Alberta reported no accumulation of trace elements in salt-affected soils (Kohut and Dudas 1993). However, the concentration of water-soluble trace elements, which are more likely to be transported during salinization, has not been investigated.

Soil salinity is conventionally defined and measured on aqueous extracts of saturated soil pastes (US Salinity Laboratory Staff 1954). This procedure offers advantages of convenience, greater extract volume relative to direct solution extraction, reproducible relationship to field soil water contents, and it compensates for variation in soil moisture retention (Janzen 1993). The trace element concentration of saturation-paste extracts from surface soils in California has been investigated (Bradford et al. 1971), but similar studies have not been done in Alberta.

The objective of this study was to determine the concentration of water-soluble trace elements in surface soils associated with saline sites in southern Alberta.

MATERIALS AND METHODS

Seventy two sites in the Brown, Dark Brown and Black soil zones of southern Alberta previously investigated by the Dryland Salinity Investigation Program (DSIP) of Alberta Agriculture, Food and Rural Development were selected for this study (Fig. 1). Causes of salinity ranged from side-hill seepage to artesian discharge. Soil samples at each site were taken from the area with the highest EM38 (vertical) readings, visible salt efflorescence on the soil surface, depressed crop growth, or the lowest landscape position.

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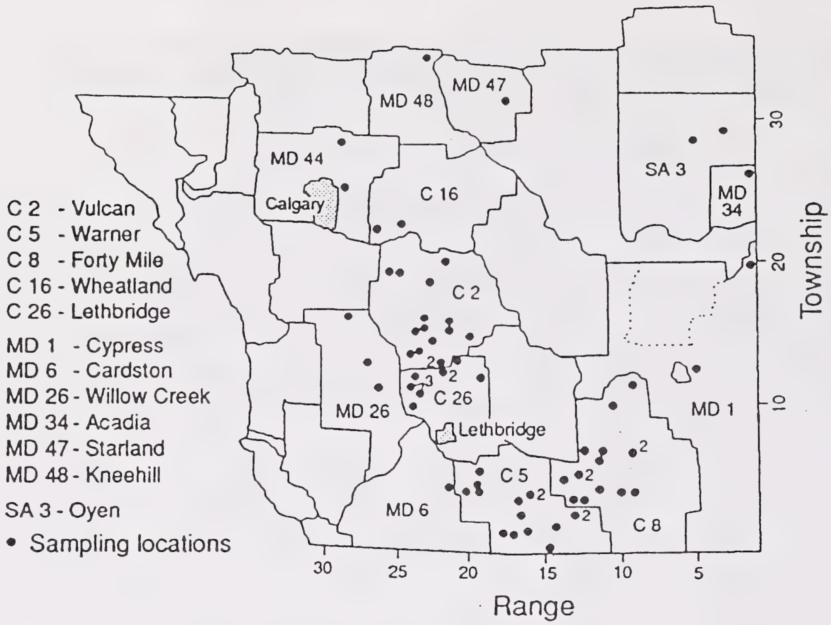

Figure 1. Location of surface soil sampling sites associated with 72 dryland saline areas in southern Alberta. Number beside dot indicates more than one sampling location.

Surface (0-30 cm depth) soil samples were obtained using a shovel at each site and stored in plastic bags. Samples were air-dried then ground in a stainless steel grinder to pass through a 2 mm sieve. Saturation paste extracts were prepared using the method of Rhoades (1982). The extract was split into two samples. Electrical conductivity (EC) and pH were measured within 12 hours on one sample (Rhoades 1982). The other sample was acidified with HNO_3 to pH <2 and stored at 4°C for a maximum of 4 months.

The water soluble trace elements Al, As, B, Cd, Co, Cu, Fe, Hg, Mn, Mo, Pb, Se and Zn were analyzed by Inductively Coupled Plasma (ICP) spectroscopy. Operating limits of detection (LOD) and limits of quantitation (LOQ) were determined for each element. The instrument was calibrated for each element before each run. Analytical values less than the LOD were recorded as below detection limit, and were treated as zero values in the statistical analyses. Statistical analyses of all data were performed using the Univariate procedure in SAS (SAS Institute 1985).

RESULTS AND DISCUSSION

Distribution of trace elements in soil saturation extracts followed a skewed distribution, and was mainly due to inclusion of values below the detection limit (0.0 mg L^{-1}) in the statistical analyses (Table 1). The CV values were >300% for Co and Se, between 200 and 300% for Hg, Cd, Zn and Mn, between 100 and 200% for Al, Cu, B, As, Pb and Mo, and 75% for Fe. Contrary to Kohut and Dudas (1993), we did not observe a direct relationship between CV and an element's mobility.

Iron and Mn were detected at >96% of the sites, Al, B, Cu and Zn at between 70 and 80% of the sites, Mo and As at between 50 and 60% of the sites, and Pb, Cd and Co at <50% of the sites (Table 1). Mean concentrations were greatest for B (2.36 mg L^{-1}), between 0.1 and 1.0 mg L^{-1} for Al, Mn, As, Hg, Fe, Zn, Se and Mo, and <0.1 mg L^{-1} for Cu, Co and Cd. Median concentrations were between 0.1 and 1.0 mg L^{-1} for B, Al, Fe and Mn, between 0.01 and 0.10 mg L^{-1} for As, Cu, Zn, Hg and Mo, and 0.0 for Cd, Co, Pb and Se.

Previously reported concentrations for saturations extracts of soils from California (Bradford et al. 1971), and estimates of typical concentrations in soil solutions (Bohn et al. 1985) are included in Table 1 for comparison. Comparisons should be made with material of similar mineralogical composition, however, these data are not available for southern Alberta. Bradford et al. (1971) reported that Zn (100%), Cu (99%) and Fe (96%) were the most frequently detected elements in saturation extracts of soils from California. Boron, followed by Mo and Al, had the highest mean values for California soils; and Zn, followed by Cu and Fe, had the highest median values. Median concentrations of Al, B, Fe, Hg and Mn in soils of Alberta were generally greater than values reported for California (Bradford et al. 1971), whereas median values of Co, Cu, Mo, Pb and Zn were generally similar. Median concentrations of As, Cd and Se were comparable to typical values estimated for soil solutions by Bohn et al. (1985).

CONCLUSIONS

In summary, over 50% of the sites sampled had detectable concentrations of the trace elements Fe, Mn, Al, B, Cu, Zn, As, Hg and Mo. Lead, Cd, Co and Se were detected in <50% of the sites. Iron, Mn, Al and B generally had the greatest % detections, and mean and median concentrations. Some median values in Alberta were greater than (Al, B, Fe, Hg and Mn) or similar (Co, Cu, Mo, Pb and Zn) to median values reported for California, or similar to estimates for soil solutions (As, Cd and Se). Boron levels as high as 6.85 mg L^{-1} may reduce wheat or barley yields on some of these saline soils.

Table 1. Summary statistics for pH, EC and trace element contents of saturation paste extracts from surface soils associated with 72 saline sites in southern Alberta, and background concentrations reported in other studies

	pH	EC	Al	As	B	Cd	Co	Cu	Fe	Hg	Mn	Mo	Pb	Se	Zn
		— dS m^{-1} —	mg L^{-1}												
Number of samples	72		72	72	72	72	72	72	72	57	71	72	72	30	72
Arthmetric $\bar{x}$	7.5	8.5	0.99	0.51	2.36	0.03	0.05	0.08	0.24	0.26	0.54	0.10	0.16	0.13	0.16
SD	0.5	14.2	0.99	0.80	2.53	0.07	0.16	0.08	0.18	0.52	1.38	0.19	0.26	0.47	0.38
CV	6.5	167	100	157	107	233	320	100	75	200	256	190	163	362	238
Minimum	6.4	0.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1st centile	6.4	0.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5th centile	6.6	0.5	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00	0.00
10th centile	6.9	0.6	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.04	0.00	0.00	0.00	0.00
25th centile	7.3	0.7	0.16	0.00	0.36	0.00	0.00	0.01	0.08	0.00	0.07	0.00	0.00	0.00	0.00
Median	7.5	1.2	0.43	0.10	0.73	0.00	0.00	0.07	0.22	0.01	0.15	0.01	0.00	0.00	0.06
75th centile	7.8	11.0	2.10	0.79	5.14	0.02	0.00	0.13	0.36	0.37	0.42	0.13	0.28	0.00	0.10
90th centile	8.1	29.6	2.50	1.45	6.13	0.11	0.11	0.18	0.43	0.80	1.00	0.33	0.49	0.00	0.22
95th centile	8.4	43.8	2.60	2.09	6.61	0.15	0.34	0.24	0.54	0.97	1.53	0.48	0.64	1.57	0.91
99th centile	8.6	65.8	2.98	4.05	6.85	0.50	1.18	0.34	1.06	3.33	10.25	0.98	1.44	1.92	2.19
Maximum	8.6	65.8	2.98	4.05	6.85	0.50	1.18	0.34	1.06	3.33	10.25	0.98	1.44	1.92	2.19
Percentage > D.L.[z]			79	54	79	33	19	75	99	51	96	50	44	11	72
Bradford et al. (1971)															
Range	7.3-8.0	0.8-16.0	<0.1-0.60	-	<0.1-26.0	-	<0.01-0.14	<0.01-0.20	<0.01-0.8	0.0002-0.0109	<0.01-0.95	<0.01-22.0	<0.01-0.30	-	0.01-0.40
Mean	-	-	0.4	-	3.06	-	0.06	0.04	0.05	0.0024	0.17	0.73	0.05	-	0.07
Median	-	-	<0.1	-	<0.1	-	<0.01	0.03	0.03	0.001	<0.01	<0.01	<0.01	-	0.04
% > D.L.	-	-	4	-	24	-	3	99	96	69	38	47	28	-	100
Bohn et al. (1985)															
Estimates[y]	-	-	-	0.1	-	0.001	0.01	0.03-0.3	-	0.001	0.1-1.0	-	0.001	0.001-0.01	<0.005

[z]D.L. = detection limit
[y]Soil solution concentrations estimated as 30x its concentration in sea water.

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MAJOR AND TRACE ELEMENT CONTENT OF SHALLOW GROUNDWATER ASSOCIATED WITH DRYLAND SALINE SOILS IN SOUTHERN ALBERTA

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INTRODUCTION

Groundwater is the main source of drinking and livestock water in rural Alberta (Hess 1981). Consequently, degradation of shallow groundwater resources, such as that associated with dryland soil salinity, is a serious concern, especially in southern Alberta (Alberta Agriculture 1986). Approximately 0.65 million ha of dryland soils in southern Alberta are affected by salinity (Sommerfeldt et al. 1984), however, the extent of groundwater contamination from salinization is unknown. An extensive survey of shallow groundwater quality associated with dryland saline soils has been conducted in Montana (Miller et al. 1978) but not in Alberta. It is important that the impact of salinity on the quality of groundwater for drinking and livestock water be investigated in Alberta, as it may affect the long-term sustainability of our groundwater resources.

Much of the shallow groundwater associated with dryland saline soils in the Great Plains region of North America is unsuitable for human or livestock consumption because of high soluble salt content (Halvorson 1990), high NO_3-N (Doering and Sandoval 1981; Sommerfeldt and MacKay 1982; Halvorson 1990), or high Se and B (Miller et al. 1978). In southern Alberta, As, Cd, Fe, Hg, Mn, Mo, Pb and Se have been found in effluent from subsurface drains underlying irrigated saline land, but at concentrations (< 1 mg L^{-1}) generally below the Canadian Water Quality guidelines (Harker 1983; Riddell 1991). We could not find any reports on the trace element chemistry of shallow groundwaters associated with dryland saline soils in Alberta.

The objective of this monitoring study was to determine the major and trace element content of shallow groundwaters associated with dryland saline soils in Alberta, to ascertain the possible impact on drinking and livestock water quality.

MATERIALS AND METHODS

Seventy two salt-affected sites in the Brown, Dark Brown and Black soil zones of southern Alberta that were previously investigated by the Dryland Salinity Investigation Program (DSIP) of Alberta Agriculture, Food and Rural Development were selected for groundwater sampling (Fig. 1). These sites ranged from side-hill seeps to those affected by artesian discharge. During the DSIP investigation, polyvinyl-chloride (PVC) wells (3.81 cm O.D.) were

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installed to approximately 6.0 m below the ground surface using a truck-mounted auger drill. At each site, the well located in the area with the highest EM38 (vertical) reading, a visible salt efflorescence on the soil surface, depressed crop growth, or at the lowest landscape position, was selected for sampling.

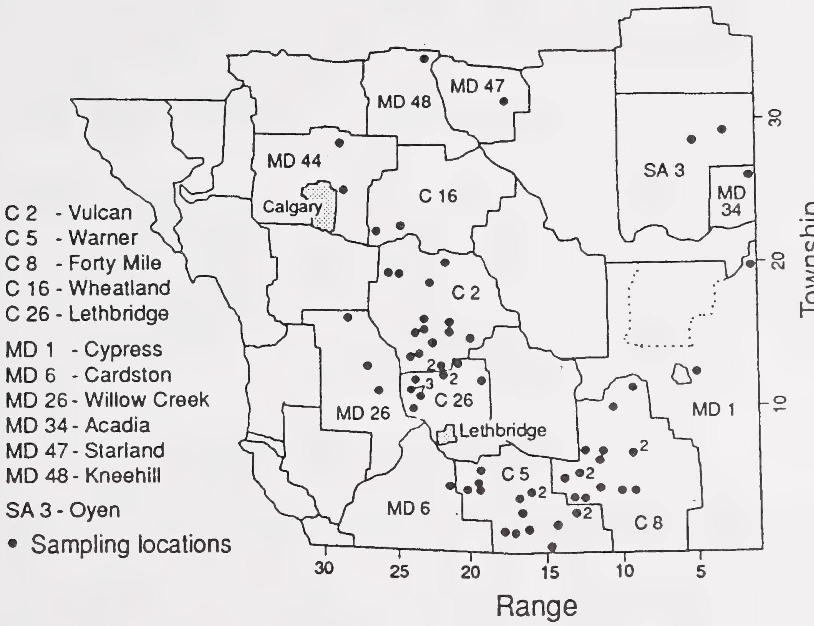

Figure 1. Location of 72 shallow groundwater sampling sites associated with dryland saline soils in southern Alberta (C=County, MD=Municipal District, SA=Special Area).

Groundwater samples were collected during the summers of 1990, 1991 and 1992. Approximately one-half the water volume in the well was purged using a WaTerra® hand-pump, and a water sample taken at about the mid-point of the water column. Wells were not completely purged and sampled the next day because previous studies in southern Alberta revealed no significant differences in organic chemical concentrations in wells before and after purging (Hill et al. 1994). Water samples were stored in 1-L polypropylene bottles, packed in ice, and transported to the Lethbridge Research Centre within 24 to 36 hours. In the laboratory, or in the field during 1992, water samples were immediately filtered (0.45 ppm) and split into two 60 ml high-density polyethylene bottles. One sample was used for major element analysis and stored at 4°C for a maximum of 2 weeks. The other sample for trace element analysis was acidified (HNO_3) to pH <2, and stored at 4°C for a maximum of 4 months.

Major element analysis was performed in the laboratory of Alberta Agriculture, Food and Rural Development in Lethbridge. Electrical conductivity (EC), pH, CO_3 and HCO_3 (acid potentiometric titration) were determined according to Rhoades (1982). Calcium and Mg were determined by atomic absorption spectrometry, Na and K by flame emission spectrometry, and SO_4-S by the turbidimetric method (Rhoades 1982). Nitrate-N and Cl were determined by the autoanalyzer method. EC values were converted to TDS values using the equation of Chang et

al. (1983) for sulfate-dominant systems.

Trace element analysis was performed in the Agricultural Soils and Animal Nutrition Laboratory, Alberta Agriculture, Food and Rural Development in Edmonton. The soluble trace elements Al, As, B, Cd, Co, Cu, Fe, Hg, Mn, Mo, Pb, Se and Zn were analyzed by Inductively Coupled Plasma (ICP) spectroscopy. The operational limit of detection (LOD) and limit of quantitation (LOQ) were determined for each element using the methods outlined by Keith et al. (1983). The instrument was calibrated for the elements of interest before each run. Data values between LOD and LOQ are statistically different from the sample blank (deionized water) at the 99% confidence level but have a coefficient of variation (CV) that may approach 100%. Data values greater than the LOQ have an uncertainty of no more than $\pm30\%$ of the measured value at the 99% confidence level.

Concentrations above (>0.0 mg L^{-1}) and below (0.0 mg L^{-1}) the LOD were used in the data analyses. The frequency distributions of the concentrations were analyzed for lognormality by performing the SAS Univariate procedure (SAS Institute, Inc. 1985) on the log-transformed values. The Shapiro-Wilk *w*-statistic (Shapiro and Wilk 1965) was calculated and tested. Large values indicate lognormality. Elements with a skewed population distribution because of many samples with concentrations below detectable limits were not transformed.

RESULTS AND DISCUSSION

The population distribution of EC, TDS, Mg, K, HCO_3, and Cl were lognormal and pH, Ca, Na, SO_4-S and NO_3-N were normal (Table 1). The dominant cation, as reflected by mean values, was Na, followed by Mg, Ca and K. The dominant anion was SO_4, followed by HCO_3, Cl and NO_3-N. Concentrations of some major ions varied from site to site, while others exhibited low variability. The CV values were highest for NO^3-N (539%), moderate for Na, SO_4-S and Ca (53-122%), and <17% for the remaining ions.

The population distribution of trace elements followed a skewed distribution, because many samples had concentrations less than the detectable limit and were treated as 0.0 mg L^{-1} in the statistical analyses (Table 2). Mean concentrations were highest (>1.0 mg L^{-1}) for B and Se, moderate (0.1 mg L^{-1}) for Al, Hg, Mn, As, Fe, Cd and Zn, and low (<0/1 mg L^{-1}) for Pb, Mo, Co and Cu. The between site variation in trace element levels was considerably higher than for major elements, with CV values highest for Zn (555%), between 200 and 225% for Pb, Co and Cu, between 100 and 200% for Cd, Mo, As, Mn, Fe and Hg, and <100% for Se, B and Al.

The recommended limits for drinking water were exceeded at more than half the sites for total dissolved solids (100%), SO_4-S, Se (86%) and Mn (75%), at less than half the sites for As (48%), Fe (40%), Cd (39%), Pb (24%), Cl (21%), NO_3-N (11%), B (1%) and Zn (1%), and at none of the sites for Cu. The recommended limits for livestock water were exceeded at more than half the sites for Se (86%), So_4-S (83%), and total dissolved solids (76%), at less than half the sites for Hg (48%), As (43%), Pb (24%), Cd (19%), No_3-N (3%) and B (1%), and at none of the sites for Ca, Co, Cu, Mo and Zn (Table 3).

CONCLUSIONS

Groundwater near saline areas may contain dissolved major and trace elements at levels

Table 1. Selected chemical parameters and concentrations of major elements in shallow groundwaters associated with saline soils in southern Alberta

	ph	EC	TDS[z]	Ca	Mg	Na	K	SO^4-S	HCO_3	Cl	NO_3-N
		dSm^{-1}	mg L^{-1}								
Number of samples	72	72	72	72		72	72	72	72	72	72
Geometric $\bar{x}$	--	7.8	6,627.4	--	345.2	--	12.5	--	694.0	91.4	--
SD	--	1.3	1.9	--	2.7	--	1.0	--	0.7	2.8	--
CV	--	16	<1	--	<1	--	8	--	<1	3	--
Arithmetic $\bar{x}$	7.7	--	--	305.2	--	2,259.5	--	2,526.2	--	--	13.9
SD	0.4	--	--	160.8	--	2,759.9	--	2,675.9	--	--	74.9
CV	5	--	--	53	--	122	--	106	--	--	539
Minimum	6.8	0.8	600.3	12.0	21.6	20.7	2.3	30.2	236.4	0.0	0.0
1st centile	6.8	0.8	600.3	12.0	21.6	20.7	2.3	30.2	236.4	0.0	0.0
5th centile	7.0	1.0	765.1	52.0	33.6	46.0	3.5	93.6	305.0	14.4	0.0
10th centile	7.2	1.9	1,537.2	68.0	57.6	126.5	5.1	185.1	323.3	18.6	0.0
25th centile	7.5	3.6	3,125.3	139.0	139.6	488.7	7.2	532.5	474.2	54.4	0.0
Median	7.7	8.8	8,184.2	369.0	390.6	1,342.1	12.1	1,774.5	709.8	77.1	0.4
75th centile	7.9	13.4	12,900.6	437.0	774.2	2,753.1	20.7	3,310.0	1,034.7	185.3	2.0
90th centile	8.1	26.5	26,964.2	474.0	1,690.8	4,919.7	28.5	7,050.0	1,357.3	374.3	11.7
95th centile	8.2	36.2	37,847.3	492.0	2,781.6	9,453.0	63.6	8,750.0	1,624.1	1,049.5	43.0
99th centile	8.6	46.4	49,570.5	560.0	6,204.0	13,041.0	80.0	11,280.0	3,016.5	4,497.3	621.6
Maximum	8.6	46.4	49,570.5	560.0	6,204.0	13,041.0	80.0	11,280.0	3,016.5	4,497.3	622.0

[z] TDS (mg L^{-1}) = 765.1 $EC^{1.087}$ (Chang et al. 1983)

Table 2. Concentrations of trace elements in shallow groundwaters associated with saline soils in southern Alberta

	Al	As	B	Cd	Co	Cu	Fe	Hg	Mn	Mo	Pb	Se	Zn
	mg L^{-1}												
Number of samples	72	42	72	72	72	72	72	72	72	72	72	42	72
Arithmetic $\bar{x}$	0.93	0.83	2.12	0.03	0.03	0.01	0.35	0.8	0.93	0.06	0.09	1.83	0.11
SD	0.65	1.28	1.49	0.05	0.06	0.02	0.40	0.9	1.31	0.10	0.20	1.52	0.61
CV	70	154	70	167	200	200	114	113	141	167	222	83	555
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
10th centile	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.0	0.00	0.00	0.00	0.00	0.00
25th centile	0.50	0.00	1.01	0.00	0.00	0.00	0.11	0.0	0.05	0.00	0.00	0.57	0.00
Median	0.98	0.00	2.09	0.00	0.00	0.00	0.25	0.0	0.49	0.00	0.00	1.57	0.00
75th centile	1.46	1.12	3.25	0.02	0.05	0.01	0.44	1.6	1.12	0.10	0.04	2.45	0.04
90th centile	1.76	2.99	4.02	0.11	0.11	0.03	0.84	2.0	2.56	0.20	0.31	3.87	0.09
95th centile	1.86	3.47	4.74	0.15	0.20	0.05	0.19	2.3	3.84	0.26	.051	4.49	0.30
Maximum	2.38	5.34	5.12	0.27	0.24	0.07	2.43	2.5	6.14	0.44	1.09	6.11	5.16
DL[z]	0.031	0.171	0.008	0.010	0.036	0.003	0.006	0.113	0.001	0.024	0.097	0.141	0.008
Percentage >DL	79	48	79	38	36	32	93	48	89	44	28	86	43

[z] = detection limit

high enough to pose a health hazard and limit animal production. Water should be tested before use by humans or livestock, especially if animals are to be fed forages grown on saline land.

Table 3. Percentage of shallow groundwater samples in southern Alberta exceeding the Canadian water quality guidelines for drinking and livestock water

	Drinking Water		Livestock Water	
	% > Guideline	Guideline[z]	% > Guideline	Guideline
		mg L^{-1}		mg L^{-1}
As	47.6	0.05	42.8	0.5
B	1.4	5.0	1.4	5.0
Ca	--	--	0	1000
Cd	38.9	0.005	19.4	0.02
Cl	20.8	250	--	--
Co	--	--	0	1.0
Cu	0	1.0	0	0.5
Fe	40.3	0.3	--	--
Hg	48.1	0.001	48.1	0.003
Mo	--	--	0	0.l5
Mn	75.0	0.05	--	--
NO_3-N	11.1	10.0	2.8	100
Pb	23.6	0.05	23.6	0.1
Se	85.7	0.01	85.7	0.05
SO_4-S	90.3	167	83.3	333
Zn	1.4	5.0	0	50
TDS	100	500	76.4	3000

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SALINITY MAPPING USING THE GLOBAL POSITIONING SYSTEM

D. Wentz and C. Livergood[1]

INTRODUCTION

The Global Positioning System (GPS) is a satellite-based radio-navigation system established by the United States Department of Defence for military positioning (GPS Positioning Guide). In recent years, this system has been adapted for civilian applications.

Since the system has the capability to accurately locate any point on earth, it can be used for a wide range of applications. One such application is the mapping of soil salinity, in conjunction with an EM38 conductivity meter.

METHODS

The Global Positioning System consists of 3 segments: a constellation of radio-navigation satellites, the ground control system, and the people using the system (GPS Positioning Guide).

Figure 1. Satellite Constellation

[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, AB T1J 4C7

The satellite segment consists of 23 active and 3 spare satellites. These satellites circle in separate orbits 22,000 km above the earth (Figure 1). They are positioned so that at least 4 satellites can be seen anywhere on the earth at any one time. These transmit radio frequency waves to receiving stations on earth.

The Ground Control segment consists of 5 tracking stations distributed around the world. The Master Control Station is located in Colorado Springs. These ground stations track satellites and compute their distance from earth.

The user segment consists of an antenna and receiver. The antenna intercepts frequency signals transmitted from as many as 8 satellites. The receiver consists of a radio frequency section and a microprocessor which records and displays satellite information (Figure 2).

Used in conjunction with an EM38 conductivity meter, each sampling point can be accurately located.

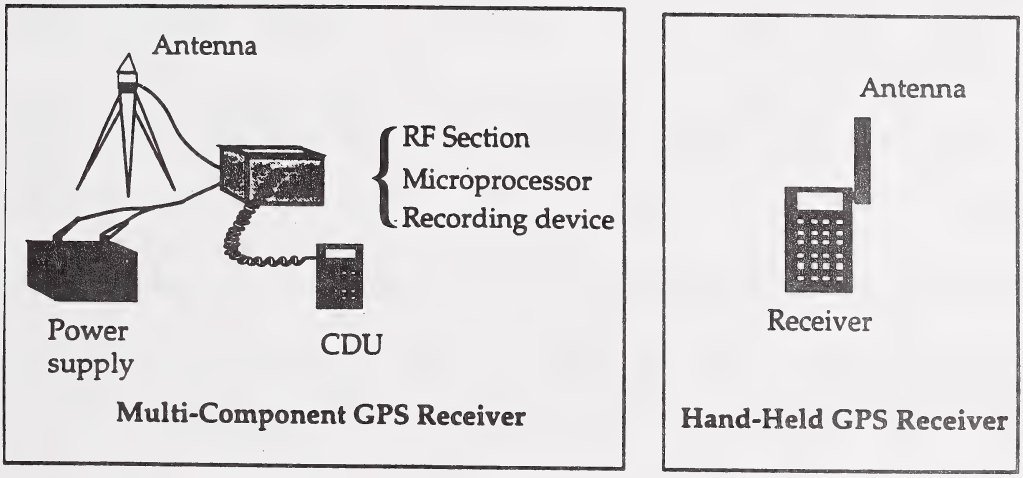

Figure 2. User segment of GPS including multi-component and hand-held units

PROCEDURES

The GPS antenna is mounted on a specially designed platform on the sled directly above the EM38 conductivity meter. The receiver and microprocessor are mounted in a dustproof and shock resistant box on the rear luggage rack of an all-terrain cycle.

Salinity mapping is accomplished in the differential mode using 2 GPS units. The first is a stationary unit located at a known bench-mark. The second or mobile unit is mounted on the sled and ATV. When the monitor station is activated, satellite information is processed and displayed on the computer screen. This includes satellite identification number, it's degree of angle in relation to the horizon and geometric strength of the satellite constellation in relation to positioning. This station remains in place until the mapping session is complete.

The mobile unit situated on the ATV, is activated and receives identical information

to the monitoring station. As the ATV and sled move around in the field, satellite information is collected by both stations. Thus, the position of the mobile unit in relation to the stationary unit is determined.

This type of mapping can produce accurate positions up to 10 km from the monitoring station.

RESULTS

The area selected for mapping is located 15 km east of Crossfield. This is part of a research project utilizing alfalfa and salt tolerant grasses to reclaim salinized land.

The investigation encompassed an area 160 by 350m. The salinity gradient ranged from strong on the east side of the site to non-saline in the southeast corner.

Initially, the perimeter of the site was mapped. This locates the boundaries of the test area which can be related to real world coordinates. Grid lines, approximately 10m apart were then run in a north south direction. When this was complete, 10 additional transect lines were run perpendicular to the grid. This established cross-over points to verify the accuracy of the GPS and EM38. Approximately 1500 data points were generated in this fashion (Figure 3).

During the griding procedure, a snowfence, weather station and tilled area were located. This was accomplished by driving around the perimeter of these areas.

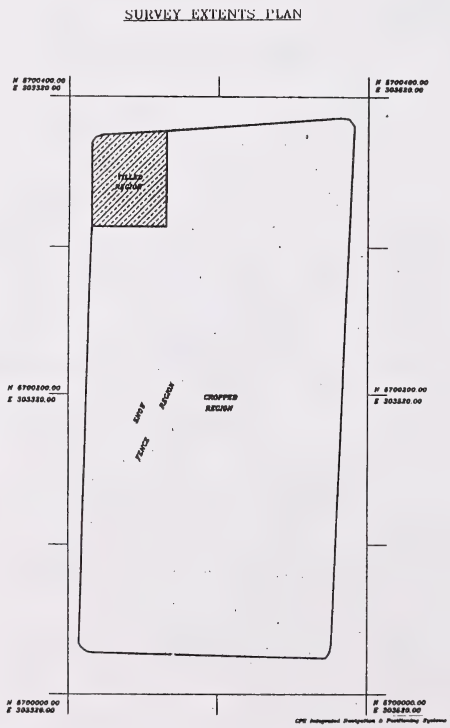

Figure 3. EM38 sampling points and cross-over lines

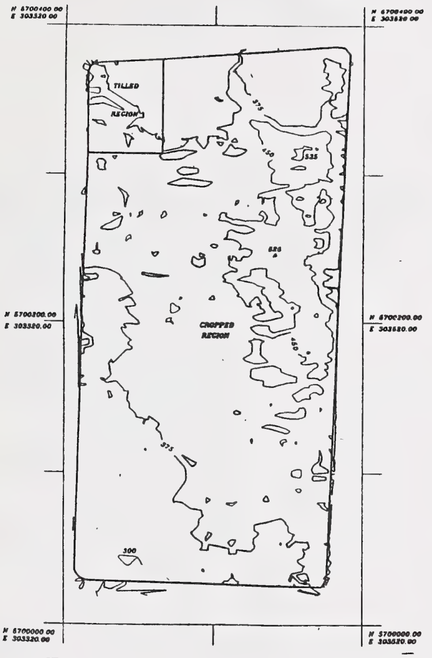

Figure 4. Elevation Contour Map

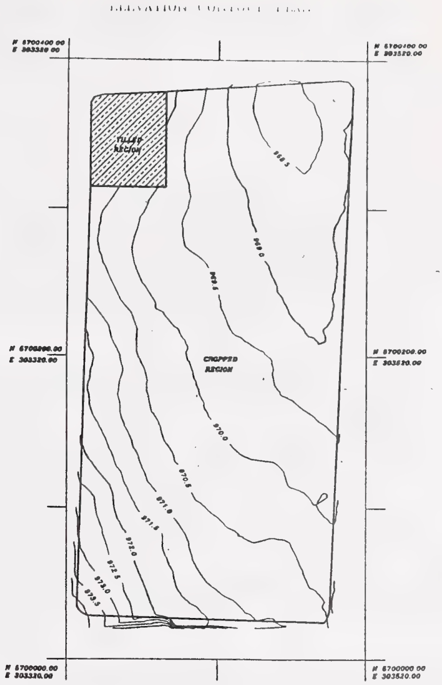

Figure 5. Salinity Intensity Map

At the completion of the griding procedure, the data is downloaded for post-mission processing. This information can be used to generate salinity intensity maps, elevation contour maps or site plan maps (Figures 4&5).

CONCLUSION

The integration of Global Positioning with the EM38 salinity mapping has reduced the amount of time and labor required to conduct salinity investigations. The absence of predetermined grid lines and the mobility of the system are conducive to concentrating data collection to severely affected areas.

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PINE COULEE SALINITY MAPPING PROJECT

D. Wentz, C. Livergood and D. Werk[1]

INTRODUCTION

In the spring of 1993, Public Works, Supply and Services requested the Conservation and Development Branch of Alberta Agriculture, Food and Rural Development to conduct a salinity inventory of agricultural land adjacent to a proposed water storage project. This project is located 6 km southwest of Stavely and runs parallel to a glacial melt-water channel known as Pine Coulee (Figure 1).

The initial request involved mapping 17 quarter sections of farmland with an EM38 meter. This was completed in May of 1993. In the spring of 1994, PWSS requested mapping of an additional 13 quarters. This was completed in the spring and fall of the same year.

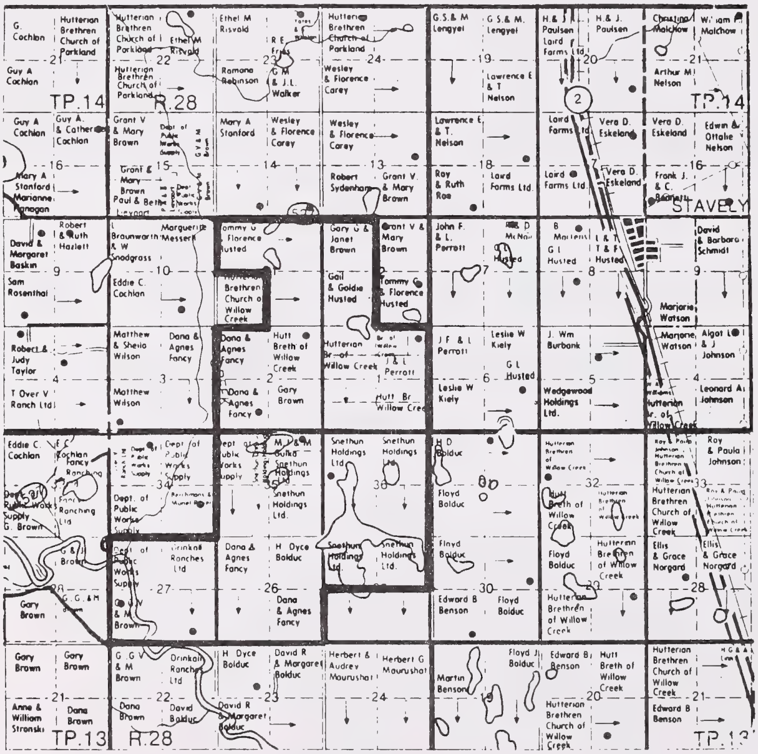

Figure 1. Pine Coulee Salinity Mapping Study Area

[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, AB T1J 4C7

This project provided the opportunity to refine and develop large scale mapping techniques using the EM38.

METHODS

The salinity inventory was conducted using an EM38 conductivity meter. The EM38 generates an electromagnetic field which penetrates the soil. This primary field induces secondary currents within the soil profile. These currents are received by the instrument and displayed as an electrical voltage. This voltage is an indication of a soil's bulk electrical conductivity (EC) to a depth of 1.5m.

Due to the nature of the field generated by the EM38, measurements are not distributed equally within the soil profile. The largest influence comes from the upper 90 cm and decreases with depth (McNeil: Technical report).

Factors such as soil temperature, texture and moisture content influence apparent conductivity. The most significant factors being soil temperature and moisture.

Temperature correction factors are used to convert raw EM38 readings to 25°C. This is the temperature at which laboratory analysis is performed.

Soil moisture is the most important factor when collecting EM38 data. Dry conditions reduce a soil's conductivity, resulting in low EM38 readings.

Table 1. Depth Weighted Electrical Conductivity Factors (Wollenhaupt 1986)

Adjusted Weighting Factors	
Soil Depth (cm)	**Depth Weighted Factor**
0 - 30	0.23
30 - 60	0.35
60 - 90	0.24
90 - 120	0.18

PROCEDURES

The EM38 is mounted in a sled manufactured with non-conductive PVC tubing. This sled is pulled by an all-terrain cycle with a microprocessor mounted on the rear luggage rack. The computer is connected to the EM38 by electrical cable. Data collected by the EM38 is transmitted to the computer and stored in a file for processing.

Mapping is accomplished using a grid type pattern starting in the southwest corner of each quarter. Grid lines run west to east and are assigned an X coordinate. The actual mapping is in a north south direction and assigned a Y coordinate. These coordinates represent a distance travelled along a grid line. Data points generated by the EM38 are assigned a Z value. Grid lines running perpendicular to the X axis are set

at 50m intervals. The distance between data points along the Y axis is determined by a 2m wheel with a switching mechanism. This distance is set at 10m. The result is a 10 by 50m grid with about 1300 data points per quarter section.

As the griding progresses, values representing the range of EM38 readings for that quarter are flagged and recorded. Soil samples are taken in 30 cm increments to a depth of 1.5m. These samples are then submitted to a laboratory for EC, SAR, pH and cation analysis. Because 82 per cent of the EM38 reading represents the upper 90 cm of a soil profile, bulk EC values must reflect this. Therefore, EC's for each 30 cm increment are weighted to a depth of 1.2m (Table 1).

Electrical conductivity values are then compared to EM38 readings by regression analysis. The resulting curves and coefficients are used to convert EM38 readings to saturated paste EC equivalencies (Figure 2).

The EC equivalencies generated in this manner are used to develop computerized contour maps. These contour maps indicate the relative differences in EC over a given area.

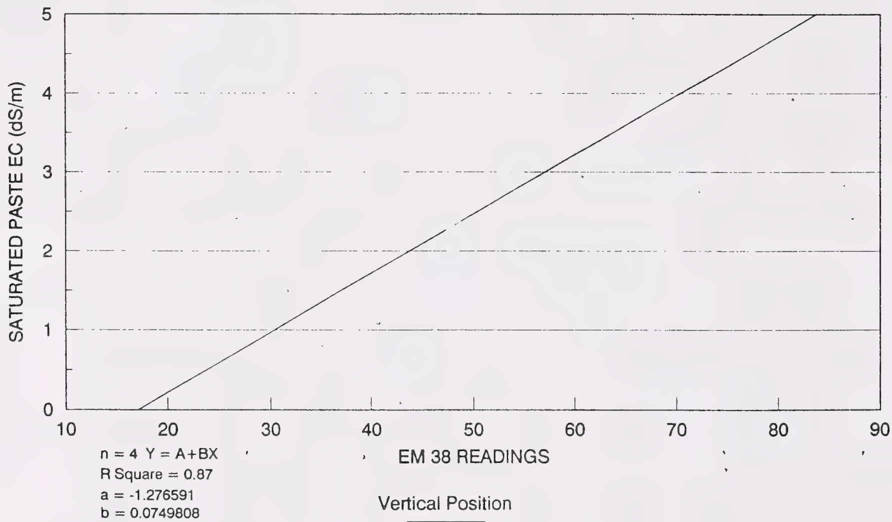

Figure 2. Regression Curve Comparing EM38 Readings to Saturated Paste EC Values

RESULTS

Saturated paste EC equivalency values were determined for each quarter by depth-weighting the EC values at each site to a depth of 120 cm. Curves comparing EM38 readings to saturated paste EC values were generated for each quarter using regression analysis. The resulting coefficients were then used to develop salinity contour maps in EC equivalent units (Figure 3).

These curves and coefficients can be used in future investigations to determine relative saline conditions using a hand-held EM38.

The study area can be divided into 2 parts: township 13 and township 14. Township 13 contains 4 quarter sections with significant salinity: NW25 with maximum EC values of 7.32 dS m^{-1}, SW26 with maximum EC values of 7.86 dS m^{-1}, NE36 with maximum EC values of 6.62 dS m^{-1} and NW35 with maximum EC values of 5.05 dS m^{-1}.

Township 14 contains 7 quarters with significant salinity. They are: NE11 with maximum EC values of 20.53 dS m^{-1}, SE11 with maximum EC values of 14.69 dS m^{-1}, NW11 with maximum EC values of 16.68 dS m^{-1}, SW12 with maximum EC values of 7.95 dS m^{-1}, NE12 with maximum EC values of 9.74 dS m^{-1} and SW13 with maximim EC values of 6.26 dS m^{-1}.

Although some of the remaining quarters contained EC equivalent values of 4 dS m^{-1} and slightly above, they can be considered non-saline. This is the point at which plants show salt related stress.

In some instances, the relationship between EM and EC values were not significant. This was due to dry conditions in the upper soil profile.

As a result of this inventory, slightly over one third of the quarters surveyed contain significant surface salinity. The remaining land is essentially non-saline.

Figure 3. Salinity Contour Map in EC Units

CONCLUSION

Incorporation of this type of mapping can produce salinity inventories of large tracts of agricultural land. This information can generate large scale salinity maps or track salt movement over a period of time.

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ROOTING DEPTH AND SOIL WATER USE OF ALFALFA IN ALBERTA 1994

Don Wentz and Bill Read[1]

INTRODUCTION

Seeding alfalfa in the recharge area of a saline seep is often the quickest, most effective way to dry the deep subsoil and stop water flow to the seep (Brown et al. 1983). Alfalfa is the plant species most often selected for rainfed salinity control because of its high moisture use requirements and deep rooting capability. Alfalfa varieties differ markedly in rooting depth, soil water extraction and yield. Furthermore, previous studies have shown the same cultivars perform differently according to soil zone. It is, therefore, desirable to investigate yield, rooting depth and moisture use requirements for the most recommended alfalfa cultivars. The above was undertaken on a soil zonal basis, under controlled conditions and during the same time period in order to develop reliable cultivar recommendations. The varieties presently recommended for this purpose are based on research results from Montana done prior to 1980, when the improved cultivars were not available.

METHODS

Three test sites at geographically different locations within Alberta were selected to conduct this study. The Oyen site is located in the Brown soil zone, the Lethbridge site in the Dark Brown soil zone and the Mundare site in the Black soil zone (Figure 1). Each site possessed uniform level topography, suitable access for demonstration purposes, the absence of shallow bedrock (>6m deep) and shallow groundwater (>3m deep) and non-saline soils (EC<4.0 dS/m).

The experimental design consisted of twelve cultivars of alfalfa, randomized and replicated four times. The study included the alfalfa cultivar "Beaver" as a base. New standard Verticillum wilt resistant cultivars Barrier and Blue J were included along with Algonquin and 120. The Flemish types included Anchor, Pioneer 532 and Apica. Three dryland varieties, Rangelander, Heinrichs and Spredor II were included with one multileaf cultivar, Multigem. Four fallow plots were established in each replication to serve as controls. Each of the plots were 2m by 6m in size.

The seed bed at each site was prepared by cultivating and harrowing. At the Lethbridge site only the herbicide Edge (ethalfluralin) was applied to control weeds. Fertilizer (11-51-0) was broadcast at a rate of 75 lbs per acre then incorporated. Each plot was seeded in May 1994 to the desired alfalfa cultivar at the recommended rate and depth using a cone type plot seeder. Row spacings were 36cm.

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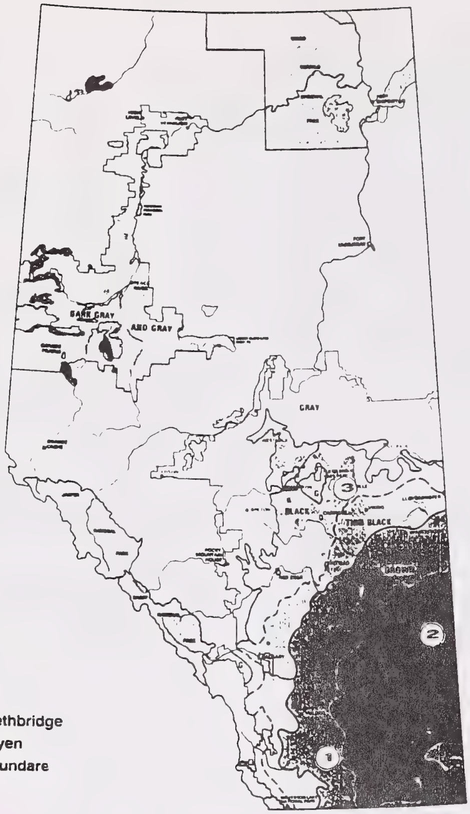

1 Lethbridge
2 Oyen
3 Mundare

Figure 1. Location of test sites

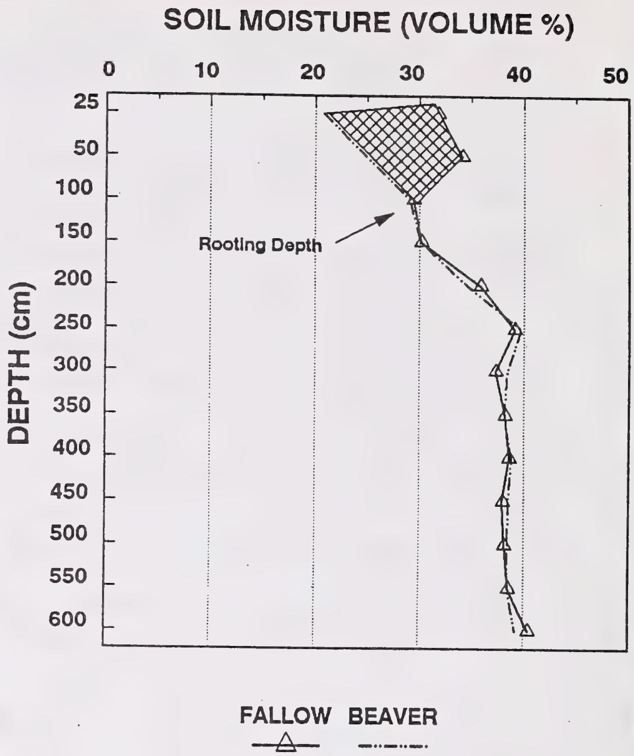

Figure 2. Example rooting depth and soil water use chart

Each plot was instrumented with a centrally located, 6m long by 5cm diameter aluminum access tube to allow for the reading of soil moisture at depth. In addition, at each of the four corners of each plot area, a 5cm diameter, slotted, PVC pipe was installed to 6m to act as water table well.

During access tube installation in each plot, soil was characterized to a depth of 600cm and sampled in 30cm increments to 150cm. The soil was analyzed for EC, SAR, pH, cations, and anions. An EM38 grid of each site was performed to confirm uniformity in soil salt content.

Once the alfalfa was established, soil moisture readings were taken biweekly using the neutron scatter technique at 25cm, 50cm and every 50cm thereafter to a depth of 600cm. At this time water table depths were recorded and crop observations were made. In subsequent years, yield determinations will be made from sampling conducted in representative areas within each plot and at such a time as to correspond with normal forage harvesting dates.

Data analysis will be based on the mean value from four plots for each cultivar. Graphs of soil moisture at depth for each variety will be plotted along with the fallow treatment soil moisture (Figure 2). The intersection of these two lines indicates rooting depth. The area from the 25cm depth to the intersection point will be planimetered to determine soil water use. At

the completion of the study, each plot will be cored and visual observations will be made to provide additional rooting depth information.

RESULTS

The first year of study (1994) in the most recent phase of this project was considered an establishment year. During this period, soil water extraction by the young crop was minimal. Mean moisture use of all varieties at the Lethbridge site was 57mm, at the Oyen site 41mm and 40mm at the Mundare site. Mean rooting depth at the Oyen site was 100cm, 101cm at the Lethbridge site and 110cm at the Mundare site. The fact that the alfalfa rooted to a depth in excess of one meter in the first year is noteworthy. There was no significant relationship between rooting depth and soil water use at any of the sites. In subsequent years, data will be presented on a varietal basis.

CONCLUSION

Approximately 647,000 ha (1.6 million ac) of Alberta farmland are affected by soil salinity and the problem is still expanding. The area of the saline seep responsible for recharging the groundwater is estimated at three to ten times the size of the seep itself (Salinity Investigation Procedures Manual 5-5). This means alfalfa could be planted on at least 1.9 million ha (4.7 million ac) of cropland to reverse the salinization process. For this purpose, results of this project will allow for the selection of the most suitable alfalfa cultivar in controlling shallow groundwater. This in hand will provide the most rapid control and reclamation of salt affected land while realizing the highest possible economic net return from the land. Determination of rooting depth, soil water use and yield for twelve different alfalfa cultivars, on the basis of soil zone, will also provide much needed, statistically verifiable information. Such data may give insight into selection criteria for the development of new alfalfa cultivars for this specific purpose.

ACKNOWLEDGEMENTS

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ASSESSING SOIL SALINITY CHANGE NEAR CROSSFIELD, ALBERTA

Don Wentz, Bill Read and Sarah Clayton[1]

INTRODUCTION

Assessing periodic change in soil salinity provides a means of determining trends in salinity status over time. This also allows for the evaluation of the effectiveness of various salinity control measures and can be used to determine the speed and degree of reclamation. Routine soil sampling for electrical conductivity from permanent sampling sites and calibrated inductive mapping can provide data for this purpose. Using regression analysis, soil EC versus time gives an indication of salinity trends at depth. Correlating percent salt affected land area versus time provides areal trends.

At a benchmark research site near Crossfield, Alberta the above two methods were used to monitor change and determine trends in soil salinity status.

METHODS

Beginning in 1991, soil was sampled in five depth increments (0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm and 90-120 cm) at four permanent sampling locations (1831-1834) within the study area (Figure 1). Electrical conductivity was determined from saturated paste extracts for each sample (Table 1). Ec for each depth was plotted against time and a linear function was calculated. The resulting curve was plotted.

Automated EM38 mapping of the study area was conducted at least twice yearly beginning in 1993. Each grid was performed according to the same spacial coordinates and was done in both the vertical and horizontal positions. EM values were converted to a saturated paste equivalent using formulas derived from calibrated EM data. Salinity contour maps of the study area were prepared and saline acreage was planimetered according to four levels of salinity (<4, 4-8, 8-16 and >16 dS/m). A percent of the total land area was calculated for each level (Table 2). Percent land area was plotted against time and the calculated linear function was graphed.

RESULTS

At Site 1831, the plotted linear curves indicate a trend towards increasing levels of soil salinity in the 15-120 cm soils (Figure 2). Salinity levels in the surface soil (0-15 cm) show a decrease over time. Trend analysis at Site 1832 indicates decreasing salinity in the 0-60 cm soils while salinity at the deeper depths has generally increased. Salinity at Site 1833 changed little

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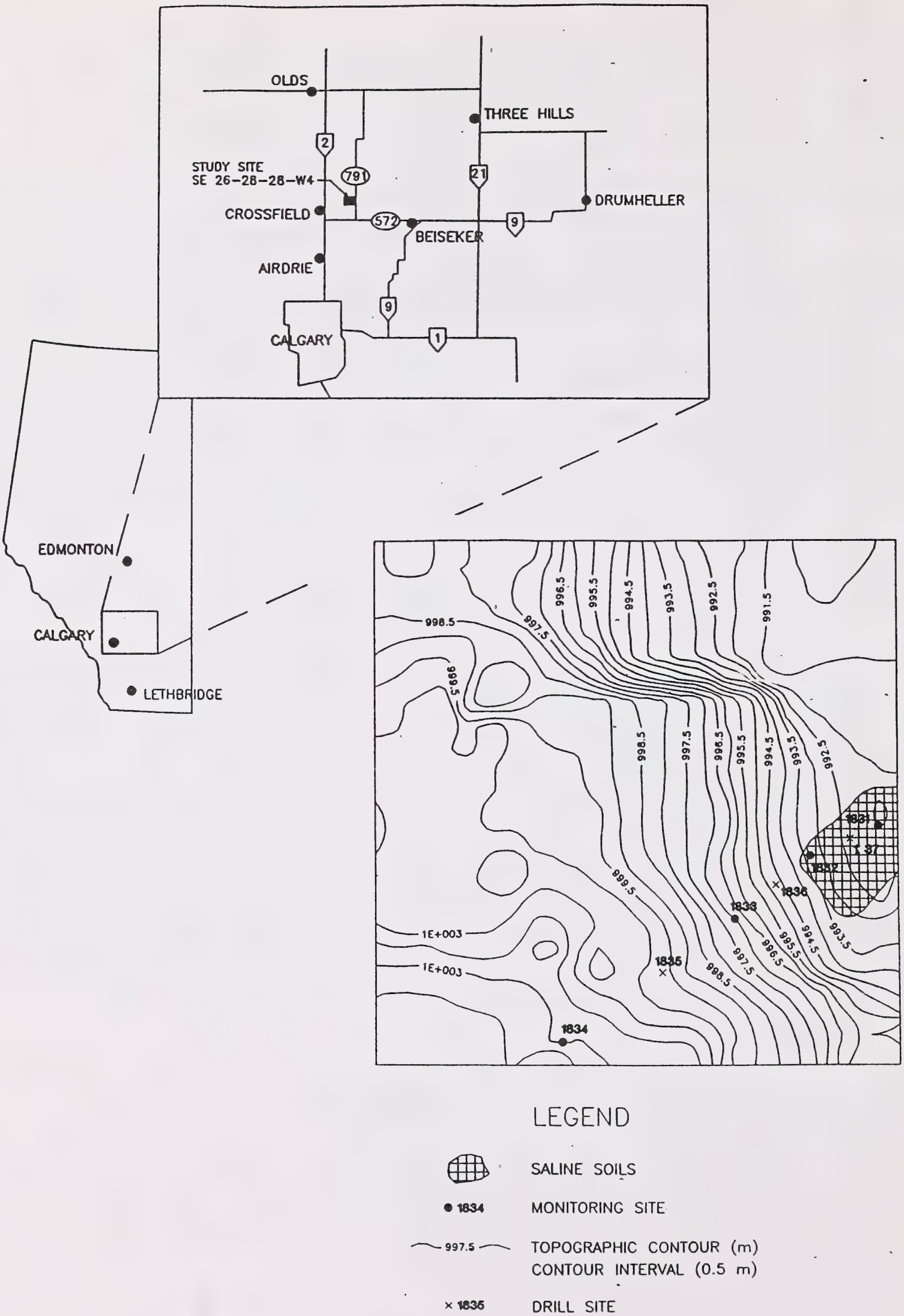

Figure 1. Location of study area and sampling sites

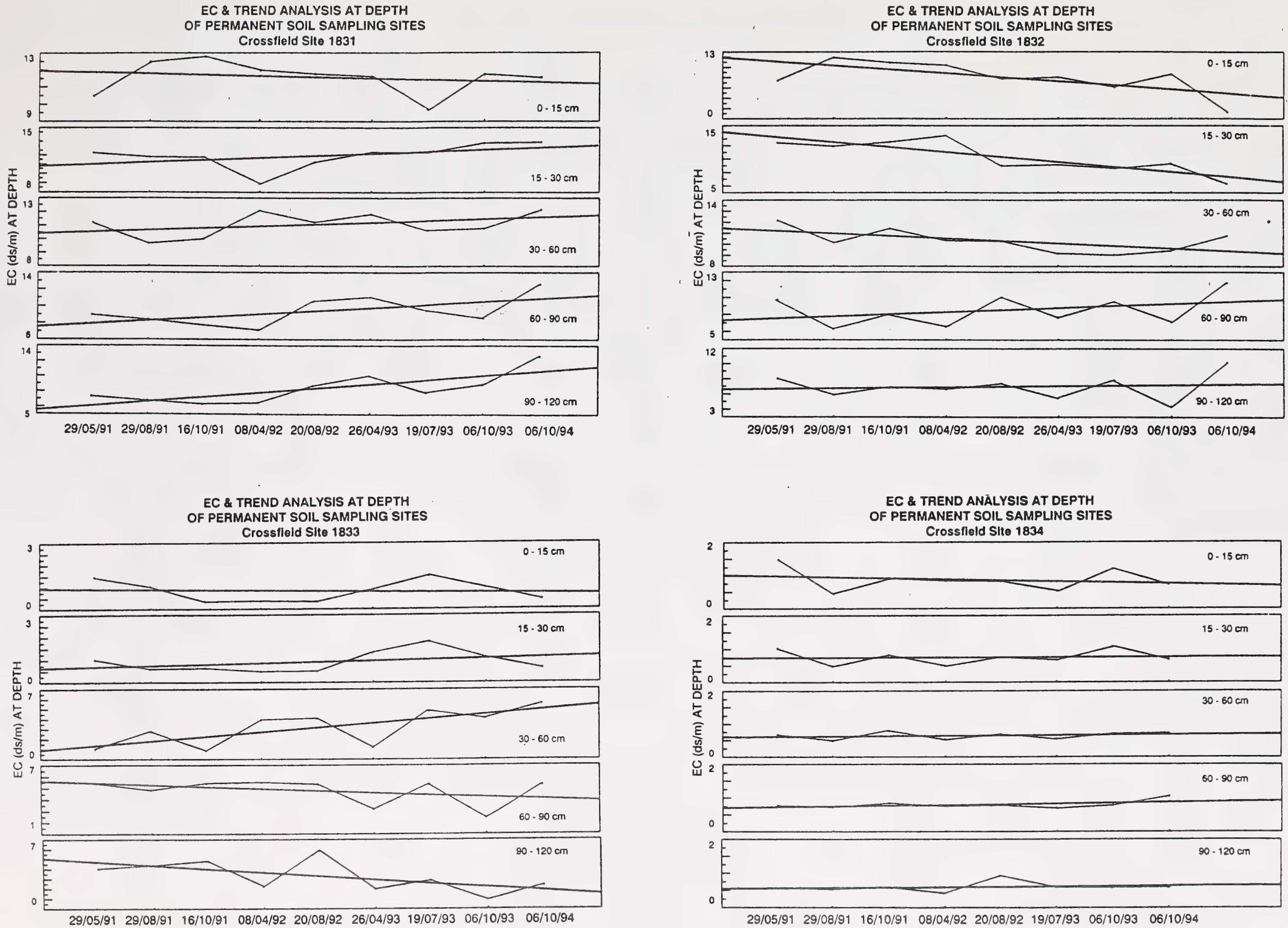

Figure 2. EC and Trend Analysis

at the 0-15 cm depth, increased slightly at 15-30 cm, increased markedly at 30-60 cm and declined at the 60-120 cm. Salinity levels at Site 1834 were stable over time with only the 0-15 cm depth showing a slight trend towards decreasing salinity.

Trends in area, according to the level of salinity, were similar whether determined using vertical or horizontal EM readings (Figures 3a and 3b). Specifically, percent area in the 4-8 dS/m range displayed a downward trend. In the 8-16 dS/m range, the trend indicated increasing area. Trends in the >16 dS/m range were towards decreasing area. There were no percent area values in the <4 dS/m range.

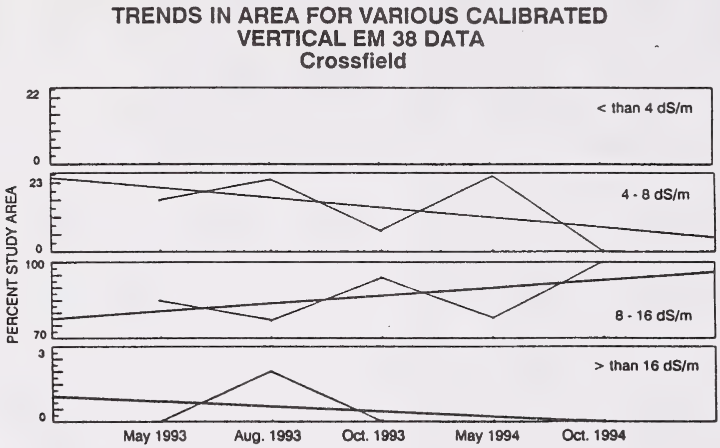

Figure 3a. Trends in Area for Various Calibrated Vertical EM38 Data - Crossfield

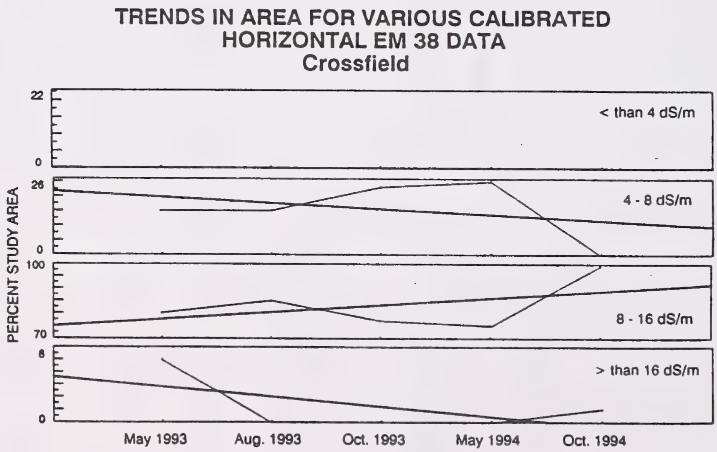

Figure 3b. Trends in Area for Various Calibrated Horizontal EM38 Data - Crossfield

Table 1. Electrical conductivity of saturated paste extracts from soil samples taken from permanent sampling sites

ELECTRICAL CONDUCTIVITY (dS/m)

Site No	DEPTH	1991			1992		1993			1994
		29/05/91	29/08/91	16/10/91	08/04/92	20/08/92	26/04/93	19/07/93	06/10/93	6/10/94
1831	0 - 15	10.47	12.48	12.78	11.99	11.76	11.62	9.68	11.73	11.54
	15 - 30	12.24	11.80	11.76	8.89	11.22	12.32	12.26	13.30	13.40
	30 - 60	11.21	9.68	10.01	12.09	11.25	11.82	10.65	10.79	12.15
	60 - 90	8.98	8.40	7.73	7.16	10.55	11.03	9.45	8.55	12.59
	90 - 120	7.32	6.83	6.33	6.48	8.75	10.05	7.89	8.92	12.65
1832	0 - 15	7.36	11.89	10.89	10.35	7.69	8.00	6.04	8.60	1.22
	15 - 30	12.41	11.90	12.53	13.50	9.03	9.14	8.61	9.34	6.31
	30 - 60	12.15	10.15	11.42	10.36	10.27	9.18	9.05	9.42	10.77
	60 - 90	9.70	6.30	7.99	6.57	10.02	7.64	9.49	7.13	11.75
	90 - 120	8.04	5.93	6.90	6.61	7.41	5.49	7.83	4.39	10.19
1833	0 - 15	1.47	1.04	0.35	0.37	0.34	0.88	1.51	0.97	0.44
	15 - 30	1.02	0.61	0.64	0.49	0.50	1.33	1.80	1.11	0.64
	30 - 60	2.81	0.86	3.93	4.07	1.20	4.81	4.08	5.52	1.13
	60 - 90	5.42	4.84	5.41	5.49	5.33	3.16	5.33	2.42	5.25
	90 - 120	4.03	4.38	4.81	2.22	5.87	1.97	2.84	0.91	2.33
1834	0 - 15	1.48	0.45	0.90	0.83	0.82	*	0.53	1.19	0.72
	15 - 30	1.02	0.48	0.82	0.49	0.75	*	0.66	1.06	0.67
	30 - 60	0.68	0.49	0.79	0.52	0.69	*	0.54	0.70	0.72
	60 - 90	0.77	0.72	0.84	0.75	0.77	*	0.69	0.77	1.04
	90 - 120	0.56	0.52	0.58	0.42	0.92	*	0.59	0.57	0.58

* erroneous data

CONCLUSION

It is possible to determine seasonal or long-term trends in soil salinity change either site specifically or on an areal basis. This can be achieved using actual soil sampling or inductive mapping. If assessing the on-site value of a vegetative control for salinity, trends in soil salinity can be determined before and after the implementation of the crop. The speed or success of the reclamation process can also be evaluated. If used as a tool to determine saline acreage and it's overall expansion or contraction, this technique is suitable.

Table 2. Percent of Study Area

Crossfield - Percent of Study Area With Various Calibrated EM 38 Data				
Date	Less than 4 dS/m	Between 4 & 8 dS/m	Between 8 & 16 dS/M	Greater than 16 dS/m
VERTICAL				
May 1993	0	15	85	0
August 1993	0	21	77	2
October 1993	0	6	94	0
May 1994	0	22	78	0
October 1994	0	0	100	0
HORIZONTAL				
May 1993	0	15	80	5
August 1993	0	15	85	0
October 1993	0	23	77	0
May 1994	0	25	75	0
October 1994	0	0	99	1

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CONSERVATION - WATER EROSION CONTROL

A METHOD FOR DETERMINING WEPP RILL ERODIBILITY PARAMETERS FOR USE IN WATER EROSION MODELLING

C.R. Wright[1] and D.S. Vanderwel[1]

INTRODUCTION

The United States Department of Agriculture (USDA) Water Erosion Prediction Project (WEPP) is a distributed parameter, continuous simulation erosion prediction model (Flanagan 1994). WEPP employs the latest advances in erosion prediction technology and is intended to eventually take the place of the Universal Soil Loss Equation (Foster 1987). Currently, efforts are under way to adapt WEPP technology for erosion prediction in Alberta.

Among other inputs, WEPP requires soil erodibility values for estimating water erosion. In WEPP, upland erosion has been partitioned into two major components, interrill and rill erosion. The rill erosion component is the topic of this paper. Input parameters for rill erodibility are K_r, the rill erodibility of a given soil due to hydraulic shear and τ_c, the hydraulic shear of flowing water below which there is no particle detachment. Measuring these values for individual soils requires an expensive and elaborate experimental procedure which involves the use of a rotating boom rainfall simulator (Elliot et al. 1989).

The procedure described by Elliot et al. (op. cit.) has K_r and τ_c measured on fallow sites by creating six 9 m long x .46 m wide ridged rill plots. Flow is induced within each rill through a combination of artificial rainfall at an intensity of (62 mm h^{-1}) and rill inflow additions of 7, 14, 21, 28 and 35 L min^{-1}. At the end of each rill flow period, the trial is stopped and data is collected in order to calculate values for K_r and τ_c through the following equations:

$$D_c = K_r(\tau - \tau_c) \qquad (1)$$

Where:
- D_c = Detachment capacity of clear water (kg m^{-2} s^{-1})
- K_r = Rill erodibility of soil due to hydraulic shear (s m^{-1})
- τ = Hydraulic shear of flowing water (Pa)
- τ_c = Hydraulic shear below which there is no detachment (Pa)

τ is a hydraulic shear parameter which represents the energy available for detaching soil particles within the rill and can be calculated as follows:

$$\tau = \gamma R_h s \qquad (2)$$

Where:
- γ = Density of water (N m^{-3})
- s = Hydraulic gradient which is the slope of the rill bottom (m/m)
- R_h = Hydraulic radius (m)

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$$R_h = \frac{A}{P} \tag{3}$$

Where: A = Rill cross sectional area (m^2)
P = Wetted perimeter (m)

In order to solve equation (1) for K_r and τ_c, D_c must first be calculated from field measurements of rill dimensions and rill sediment delivery characteristics using the following equation:

$$D_c = -\frac{T_c}{w_r L} \ln\left(1 - \left(\frac{Q_s}{w_r T_c}\right)\left(\frac{D_c'}{D_c' + E}\right)\right) \tag{4}$$

Where: T_c = Transport capacity along the length of the rill (kg s^{-1})
w_r = Rill width (m)
L = Rill length (m)
Q_s = Sediment delivery rate from the rill plot (kg s^{-1})
D_c' = Detachment capacity for a given flow as calculated by equation (1)
E = Measured interrill detachment rate (kg m^{-2} s^{-1})

Transport capacity represents the maximum amount of sediment that can be transported by flow within the rill when detachment is not limiting and is given as:

$$T_c = w_r \beta \tau^{1.5} \tag{5}$$

Where β is the transport coefficient for a given soil and represents a weighted average based on the aggregate size distribution of the eroded sediment leaving the rill.

To derive values for K_r and τ_c, D_c was calculated from equation (4) for each flow trial using transport capacity (T_c), rill width (w_r), length (L) and sediment delivery rate (Q_s). Next, D_c was plotted against hydraulic shear (τ) at each flow rate. Linear regression was used to determine the slope (K_r) and τ intercept (τ_c) values of the resulting relationship. This allowed calculation of D_c' using equation (1). D_c' was substituted back into equation (4) and the new value for D_c was plotted against τ. After several iterations, stable values for K_r and τ_c emerged.

METHODS

Since a rotating boom rainfall simulator was not available for this study, rill erodibility trials were conducted using rill inflow additions only. Laflen (pers. com. 1994) suggested rill erodibility could be determined without the use of a rainfall simulator but cautioned some controversy exists regarding this methodology. During natural rill erosion, sheet wash from rainfall delivers a significant amount of sediment to the rill, adding to the

total rill sediment load. At this time, it is unknown how rill detachment rates will be affected with the absence of rainfall during test runs.

WEPP erodibility studies must be conducted on a clean tilled fallowed soil free of surface residue and root mass accumulations. To achieve this a fallow condition must be maintained for a minimum of three growing season months prior to the test.

Field tests were conducted on a Breton Loam at the University of Alberta Research plots located 2 km south east of Breton Alberta. A uniform area, sloped approximately 5%, with a westerly aspect was selected. A fallow condition had been maintained for 2 years prior to the test. Before constructing rill plots, a seed bed condition was established with a 2 m spring tooth field cultivator equipped with tine harrows. Following cultivation, a survey level and rod were used to establish the exact location of rill plots to ensure that each plot was uniform and had a 5% slope. Rill centres were marked by stretching a 10 m long string between two stakes. Spacings between individual rill plots did not exceed 2 m. Two parallel rill containment ridges 25 cm high, 40 cm apart were prepared on each side of the rill centre (marked by string) by shallow scooping of the Ap horizon from the adjacent area outside the space occupied by the rill plot. The objective was to contain the rill flows and to provide a sufficiently deep layer so that scouring by rill flow would be contained within the Ap horizon. A wooden template with 30 degree side slopes was used to shape the containment ridges, providing a smooth sided evenly sloped rill containment channel.

Rill plots were saturated over a 12 hour period by applying water to the centre of each rill plot using a gravity fed laser-drip-tube irrigation system. Immediately prior to running water down each rill, a small stilling basin was installed at the upstream end of the rill. At the downstream end, the rill cross section was exposed by digging a large sampling pit which received an open ended sheet metal trough installed 15-20 cm below the rill bottom. This functioned to convey rill runoff into sample containers.

Each rill was subjected to five flow rates except rill 1 which had six. Target flow rates were delivered in ascending order with a commercial flow meter accurate to $\pm$ 1% at 12, 19, 26, 33 and 40 l min^{-1}. Flow duration was 10 minutes for the first flow rate with sampling starting after 5 minutes of flow. Subsequent flow rates lasted for 7 minutes with sampling starting after 2 minutes. Six 1 L sediment samples were taken during each flow trial at 50 second intervals and later analyzed for sediment concentration. Sediment samples were collected in wide mouth plastic containers which allowed sampling of the entire flow cross section. In order to calculate average hydraulic shear (τ), at the end of each flow trial 10 rill cross sections, spaced 0.9 m apart, were measured at preset locations with a small rill meter. After completing rill meter measurements a higher flow rate was introduced into the rill until sediment sampling was complete. After all five flow rates had been introduced into the rill the average slope of the rill channel was surveyed using a survey level and rod. Rill length was measured with a tape.

Data Analysis

In order to simplify field data collection and the calculation of K_r and τ_c a modification of equation (1) has been used in the past (Elliot and Laflen 1993, Norton and Brown 1992, West et al. 1992) where D_c was replaced by D_r:

$$D_r = K_r(\tau - \tau_c) \tag{6}$$

Where D_r represents actual rill detachment rate in kg m^{-2} s^{-1}.

The following procedure describes the process by which rill erodibility parameters were calculated. This procedure differs from the one used in this study. Using equation (6) allows K_r and τ_c to be calculated without the use of equations (4) and (5) and the ensuing iterative regression analysis. Hydraulic parameters used to determine τ were calculated by using the continuity equation:

$$Q = AV \tag{7}$$

where : Q = Rill discharge
A = Cross sectional area of rill
V = Average velocity of flow in rill

Rill discharge (Q) was measured directly, average velocity (V) was determined by injecting dye at some point in the rill flow and determining leading edge flow velocity and multiplying by experimentally derived ratios of average velocity to maximum velocity. Rill cross sections were assumed to be rectangular and thus rill cross sectional area was determined as rill width multiplied by rill depth. Rill width (w_r) was measured directly and rill depth (d) was calculated by rearranging equation (7):

$$d = \frac{Q}{Vw_r} \tag{8}$$

Hydraulic shear (τ) for each flow rate was calculated from equation (2) Where:

$$R_h = \frac{A}{2d + w_r} \tag{9}$$

To calculate D_r, sediment concentration was multiplied by measured flow rates and divided by the rill surface area (rill width multiplied by rill length). This was based on the assumption that if very little detachment occurs from the edges of the rill then some representative width other than wetted perimeter must be used to calculate the soil area from which detachment occurs. The rills which developed on the Breton loam were observed to increase in width throughout the duration of all runs and therefore detachment was occurring from the rill sides.

For this study K_r and τ_c were computed using equations (6), (2) and (3). A small rill meter with 7 mm pin spacings was used to measure 10 rill cross sections after each flow trial. With the rill meter, detailed measurements of rill width, depth, cross sectional area, and wetted perimeter could be obtained anywhere along the rill. This allowed direct calculations of hydraulic parameters from each rill cross section. Values of τ were calculated for each cross section using equations (2) and (3) and averaged to determine τ for each flow trial. Sediment detachment was computed by taking the average sediment concentration for each flow trial multiplied by the flow rate, divided by soil surface area in

contact with the flowing water. Surface area was computed from 10 wetted perimeter measurements and the total rill length. D_r was plotted against τ for each flow trial. Linear regression was used to define the relationship between D_r and τ. Values for K_r correspond to the slope of the regression line and τ_c was determined by setting $D_r = 0$ and calculating where the regression line crossed the τ axis line.

RESULTS AND DISCUSSION

Sediment concentration data obtained from each rill at each flow trial are shown in Figure 1. The sediment concentration between samples at any given flow rate was variable. This was expected as periodic events such as sidewall slumping and head cutting tend to instantaneously release relatively large volumes of sediment into the flow, momentarily increasing sediment concentration. As a result, the method of taking 1 L grab samples produced some samples which had large values for sediment concentration.

Except for Rill 3, as flow rate increased sediment concentration did not increase. Even though sediment concentration did not seem to increase with higher flow rates, the rate of soil loss (erosion) from the rill plots did increase. The rate of erosion from the rill plots can be calculated by multiplying sediment concentration by the flow rate. Thus at higher flow rates even though sediment concentration did not increase the rate of erosion increased.

Individual rill slopes ranged from 5.0-5.9% with a mean of 5.4%. Values for τ from each flow trial were calculated for every rill cross section using equation (2), where s was represented by the average rill slope. Average values for τ were then calculated for each flow trial and plotted against the corresponding values for D_r. Linear regression analysis of the results (Figure 2a) yielded values for K_r and τ_c of 0.00177 s m^{-1} 2.34 Pa, respectively with R^2=0.64. One outlier from rill 5 was removed, improving R^2 to 0.72. This rill was observed to be noticeably deeper and more well defined with fewer depositional areas than the other rills. Sediment concentrations ranged widely (Figure 1) suggesting this rill experienced more frequent episodes of sidewall slumping, and head-cutting. As a result 6 sediment samples may not have been sufficient to characterize detachment rates during each flow trial causing a poorer correlation between τ and D_r.

K_r and τ_c were computed using the same process (Figure 2b) except each rill was assumed to have the same slope. This improved the R^2 values to 0.70 for the raw data and 0.76 for the data with one outlier from rill 5 removed. By not adjusting τ for individual rill slopes, the strength of the τ vs D_r relationship improved. The measured difference in vertical distance between the highest and lowest sloped rill was 8 cm (0.9%). The slope at any given reach within the rill can vary widely. For example at head cuts, the channel bottom slopes steeply and may actually be undercut. Along reaches of the rill where deposition is occurring rill slopes are much flatter than the average slope. In addition, the placement of the rod during surveying was subjectively based on what was thought to be representative of the entire rill. Slope measurement error could have possibly been in the order of ±5 cm (±0.6%). These small discrepancies may have produced misleading average rill slopes. It may be more appropriate to adjust τ based on the land slope rather than surveying

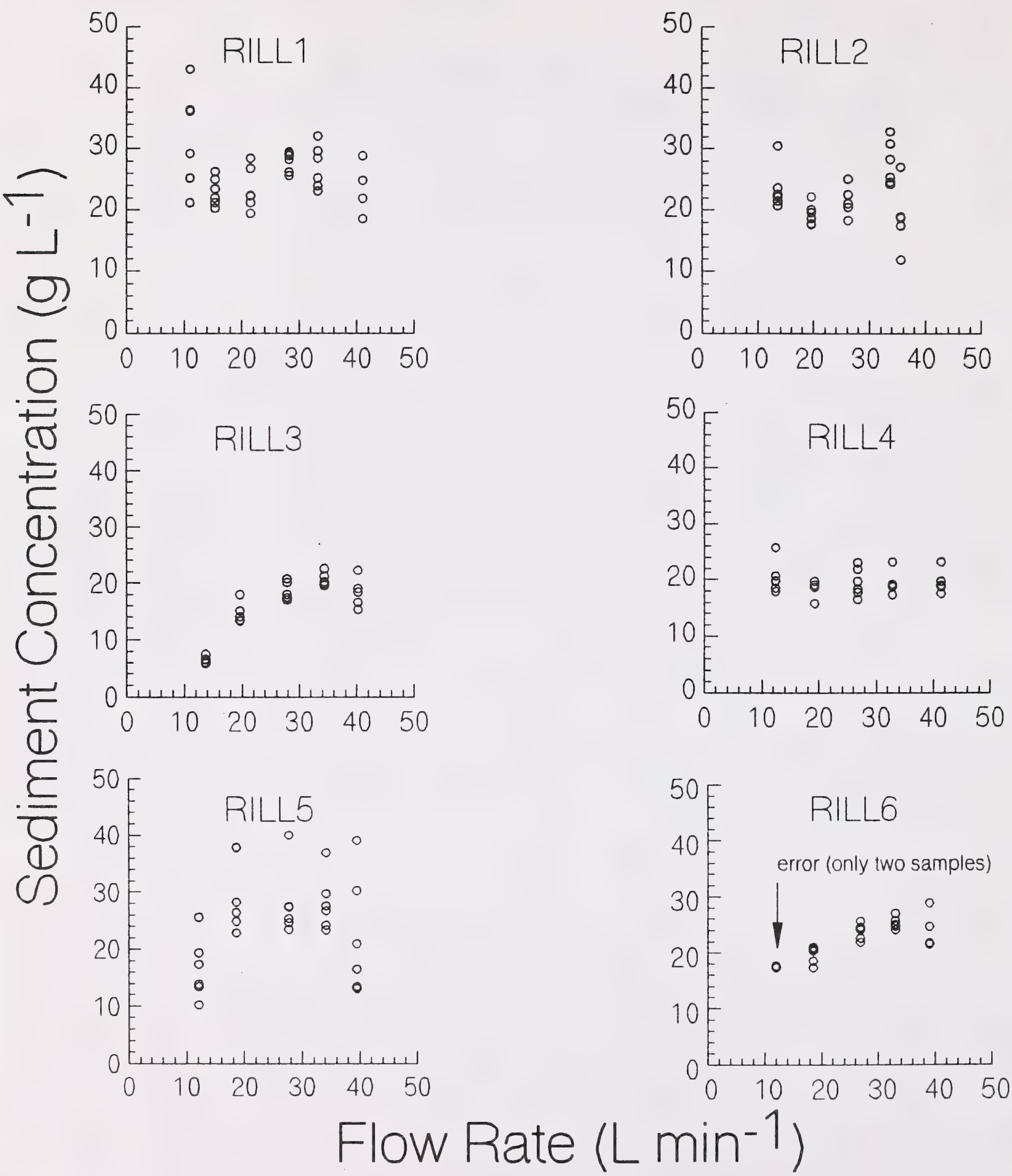

Figure 1. Sediment concentration as a function of flow rate for individual rills.

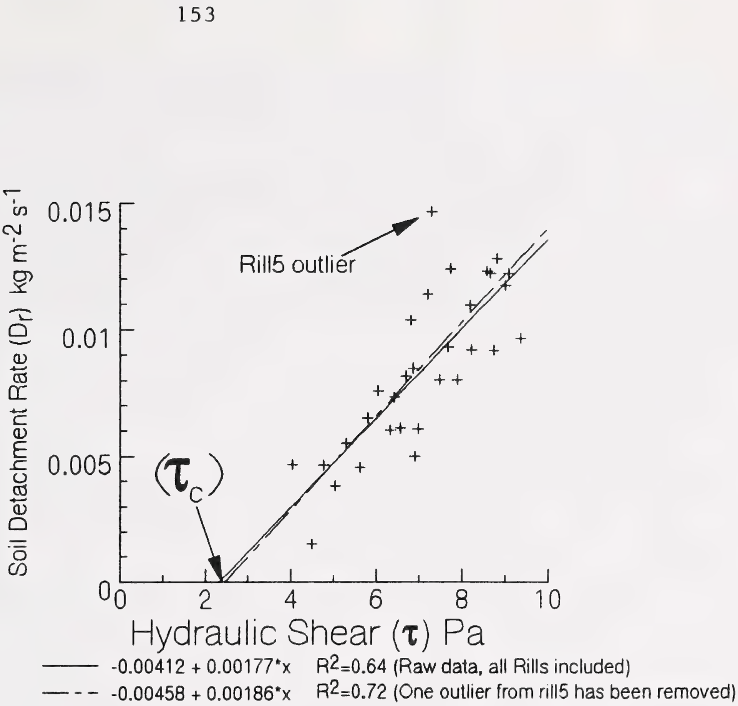

Figure 2a. Rill erodibility response for six rills. Hydraulic shear has been calculated using the actual slope values for each rill.

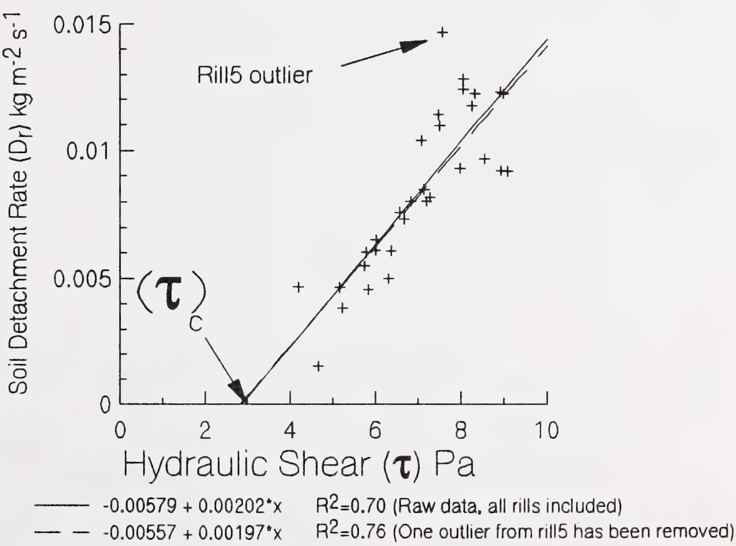

Figure 2b. Rill erodibility response for six rills. Hydraulic shear has been calculated using the same slope value for each rill.

individual rill slopes. Further tests on other soils are needed in order to verify this approach. However, for the Breton Loam, adjusting τ for individual rill slopes resulted in poorer correlations between τ and D_r.

Regressions analysis of τ vs D_r were performed for individual rills (figure 3). R^2 values for individual rills improved over the lumped regression analysis of all rills and ranged from 0.67 to 0.97. Four of the six rills had R^2 values in excess of 0.89 indicating that τ was highly correlated with measured sediment detachment rates. Relatively low R^2 values of 0.72 and 0.67 were obtained from rills 2 and 5, respectively. Poor correlation was obtained for rill 2 because of excessive values for measured sediment concentration recorded during one flow period. Sediment concentrations may have been elevated by chance sampling when runoff was momentarily carrying higher sediment loads associated with periodic episodes of slumping and or head cutting. This problem may be solved by taking larger sediment samples, more sediment samples, or by obtaining one representative sample collected by consistently sampling a small percentage of the runoff at frequent intervals throughout the duration of the run. The reasons for the poor correlation from rill 5 were discussed previously.

For the 6 rills, K_r ranged from 0.00134 to 0.0026 s m^{-1} and τ_c ranged from 0.95 to 4.54 Pa. Rill 4 produced the lowest values for K_r and τ_c values, 0.00134 s m^{-1} and 0.95 Pa, respectively. Rill 4 did not exhibit any visual differences in rill development or final rill morphology when compared to the other rills. However, the R^2 value for rill 4 was 0.90 suggesting that within very short distances, less than 10 m, soil erodibility can vary widely. Thus when characterizing the erodibility of a specific soil type, it is very important to select representative test sites and replicate trials.

CONCLUSIONS

In linear regressions of τ vs D_r for individual rills using a simplified formula, R^2 values ranged from 0.67 to 0.97. When the same data from all rills were lumped and one outlier removed, the R^2 value was 0.72. This was improved to 0.76 when average slope values were assumed for all rills suggesting that the slope factor used for calculating τ should be based on land slope rather that individual rill slopes. R^2 values in rills 2 and 5 were the lowest at 0.72 and 0.67, respectively which resulted from a single outlier in each data set. Both outliers were linked to unusual measured values for sediment concentration. This was likely caused by taking 1 L grab samples at discrete intervals throughout the flow trial. As a result, some samples may have had elevated sediment concentrations resulting from periodic episodes of sediment enrichment caused by side wall slumping and head cutting.

In the past, in addition to introducing flow into the top of preformed rill channels, WEPP erodibility measurements were conducted with a rainfall component delivered by a large rainfall simulator. A rainfall simulator was not available for this test therefore the experiment was performed by introducing flow at the top of the rill. From the regression analysis it is evident that the hydraulic shear vs detachment relationship developed by WEPP modellers works well even in the absence of rainfall. However, more soils will have to be tested in order to determine how measured values of K_r and τ_c will be affected without the use of a rainfall simulator.

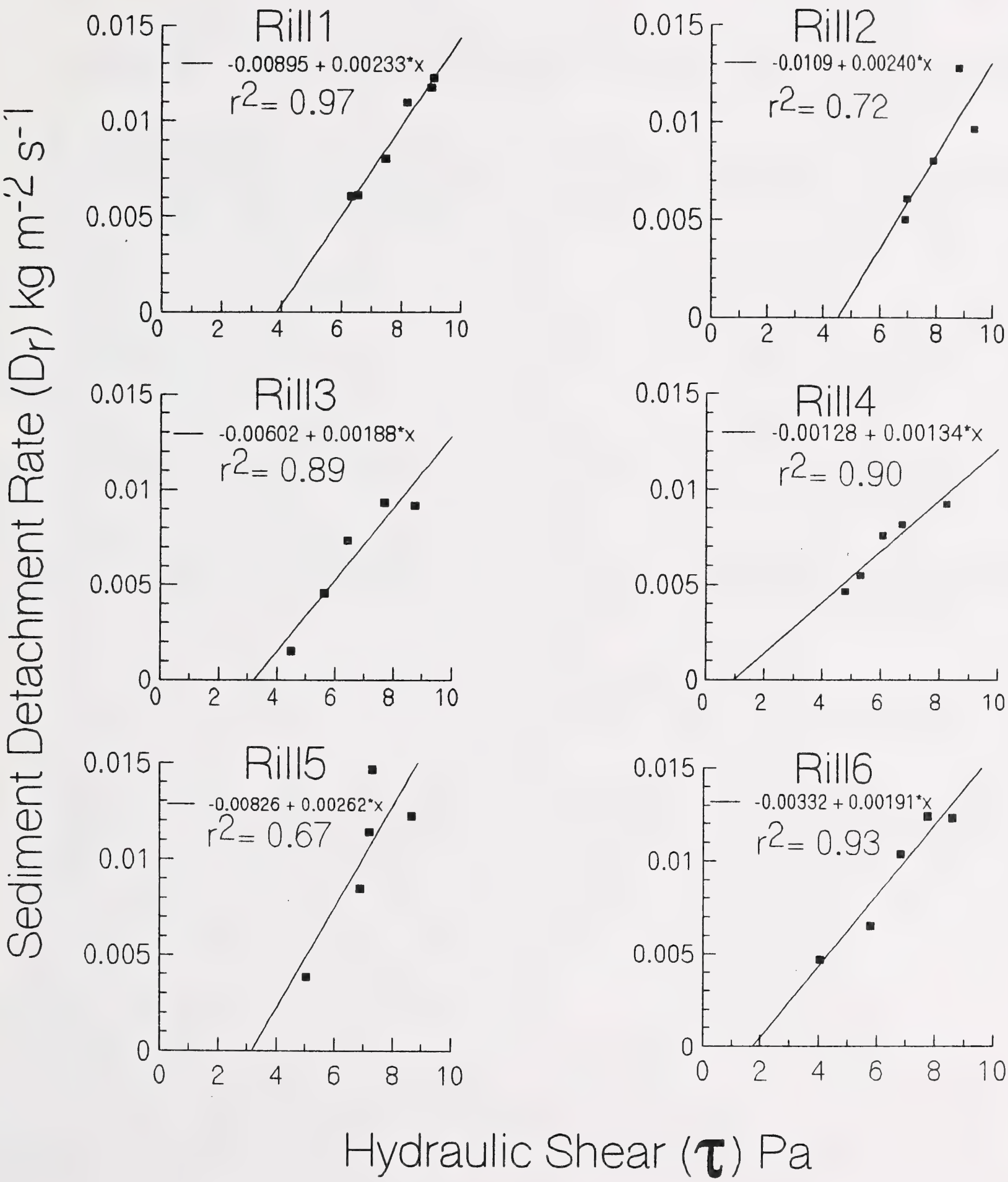

Figure 3. Rill erodibility response for individual rills.

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EROSION OF AGRICULTURAL LAND IN THE PEACE RIVER REGION OF ALBERTA

C.R. Wright[1] and D.S. Vanderwel[1]

In 1976, a committee meeting of the Environment Conservation Authority recommended that northwest Alberta including the Peace River region be recognized as an area that differs from the rest of Alberta in characteristics and conditions related to erosion. Chanasyk and Woytowich (1984) attributed severe erosion problems in the Peace River region to the large population of Solonetzic soils and Solonetzic subgroups of the Chernozemic and Luvisolic orders. The soils in the Peace River region typically have fine textured surface horizons overlying shallow slowly permeable subsurface horizons (Standing Senate Committee on Agriculture, Fisheries, and Forestry 1984). Shephard (1975) identified Luvisolic soils as high risk soil types due to the relatively impervious subsoil.

During mid June of 1990 a heavy rainfall resulted in severe flooding and erosion near Grande Prairie, in the Peace River region. In response, the Alberta Government initiated a Disaster Assistance Program which was designed to help offset the cost of reclaiming water erosion damaged lands. Through the program, a data base was created which among other information, contained the legal locations of erosion damaged areas. This permitted a systematic analysis designed to identify high risk water erosion soil types within the study area.

METHODS

Disaster Assistance files provided data on the legal location of damages resulting from a large storm in June of 1990 and included; gully erosion, rill erosion, and sheet erosion. Soils information was obtained from the Soil Inventory Database for Management and Planning (SIDMAP) which is a digitized database containing information on climate, soils and landscape features (Hiley et al. 1986). SIDMAP data for the study area was available at the section level. The size of the study was defined by the locations of the Disaster Assistance applications. Information obtained from rainfall maps was provided by Environment Canada.

A Relational data base program was used to link Disaster Assistance information to the soils information contained within SIDMAP. A Geographical Information System (GIS) was used to combine rainfall information from the storm with the linked SIDMAP and Disaster Assistance files. Data base queries were designed to examine the sensitivity of soils to rainfall erosion.

In an attempt to reduce the interactions between different rainfall amounts and the spatial variability of soil types within the relatively large study area, comparisons were performed

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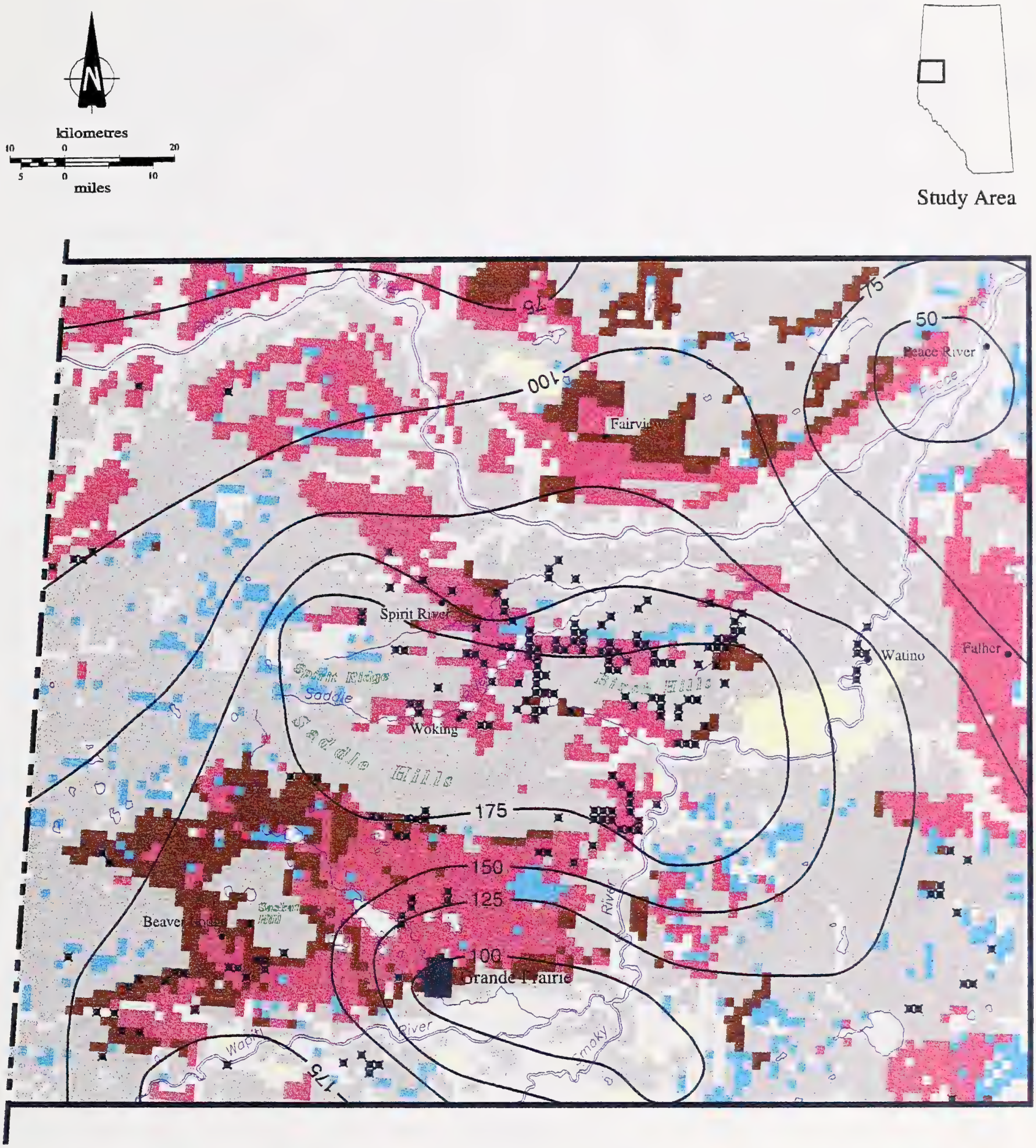
within rainfall contour intervals. Comparisons were made based upon the average damage density within each contour interval and upon the actual damage density associated with each soil type. The average damage density was calculated for each rainfall contour interval by dividing the total number of damaged sections by the total number of sections within the contour interval. Similarly, damage density was calculated for each soil type and compared to average damage density. If a specific soil type had a damage density which was higher than the average damage density then that soil type was considered to be a high erosion risk area.

RESULTS

Figure 1 shows rainfall contour information and erosion damaged sections overlaid onto the SIDMAP soils information. In total, 198 sections of land received some form of Disaster Assistance. Almost 90% of the damaged sections occurred in areas that received over 125 mm of rain. For simplicity the following analysis was confined to areas receiving over 125 mm of rainfall. The results are shown in Table 1.

TABLE 1. Inventory of Soil Orders and Erosion Damages Within Rainfall Contours

Rainfall (mm)	Soil Order	total sections	area (%)	Sections Damaged	Damage density average	Damage density actual
200-175	Solonetzic	214	16	32	0.062	0.149
	Luvisolic	805	61	38	0.062	0.047
	Chernozemic	33	3	7	0.062	0.212
	Undefined	226	17	5	0.062	0.022
	Miscellaneous	33	3	0	0.062	0.000
	Total	**1311**	**100**	**82**		
175-150	Solonetzic	375	22	32	0.042	0.085
	Luvisolic	731	43	20	0.042	0.027
	Chernozemic	301	18	11	0.042	0.037
	Gleysolic	104	6	3	0.042	0.029
	Undefined	176	11	5	0.042	0.028
	Total	**1687**	**100**	**71**		
125-150	Solonetzic	259	14	10	0.013	0.039
	Luvisolic	1051	58	5	0.013	0.005
	Chernozemic	86	5	2	0.013	0.023
	Gleysolic	92	5	1	0.013	0.011
	Undefined	329	18	6	0.013	0.018
	Total	**1817**	**100**	**24**		



Legend

Solonetzic
Luvisolic
Chernozemic
Gleysolic
Miscellaneous
Undefined
Erosion Damaged Site

Contour lines and values indicate millimetres of precipitation

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Figure 1: Soil Orders and Locations of Erosion Damaged Sites

Compiled by Conservation and Development Branch

Damage density was highest in the contour interval receiving the most rainfall and lowest in the contour interval which received the least amount of rainfall. Thus the frequency of damage increased with increasing rainfall depths. Within all rainfall contours, soils belonging to the Solonetzic order had damage densities in excess of the average damage density. This suggests that Solonetzic soils were particularly susceptible to water erosion.

Tajek (pers. com. 1994) stated that infiltration into the Ap horizons of Solonetzic and Luvisolic soils was generally not limiting. However, infiltration of water through the Bn or Bnt of a Solonetzic soil or the Ae and Bt horizons of a Luvisolic soil can be very low particularly if the soil is saturated. When dry, the Ap horizon of these soils is capable of absorbing and storing a certain amount of rainfall. However, once saturated, infiltration will be controlled by subsurface horizons which, in the case of Solonetzic and Luvisolic soils, may be quite impermeable. Since the event (rainstorm) which caused this erosion was of low intensity and long duration, for the most part, infiltration would have been controlled by the relatively impermeable subsurface horizons.

Damage density on the Luvisolic soils was much lower than average damage density for each rainfall contour. Luvisolic soils characteristically develop under forest vegetation. Extensive land clearing in the Peace River region has permitted farming on this soil type. However, a large percentage of the mapped Luvisolic soils are still under forest cover. Therefore the low values for damage density associated with this soils type is likely an artifact resulting from the large proportion of Luvisols which occur under forest vegetation. Ideally this analysis should have incorporated land use information for calculating damage densities. Unfortunately this data does not exist in Provincial data bases in sufficient detail. Generating this information would be both time consuming and expensive.

Within two rainfall contour intervals, 200-175 mm and 150-125 mm, Chernozemic soils had damage densities in excess of the average damage density. However, since only a small portion of the land base was represented by Chernozemic soils within these contour intervals and only a few sections were damaged, it is difficult to attribute high damage densities to Chernozemic soils. Within the 150-175 rainfall contour interval, almost 18% of the soils were Chernozemic. Damage density was lower than average density. Chernozemic soils typically do not have restrictive subsurface soil horizons. Thus, infiltration rates are higher, permitting the soil to absorb more rainfall, resulting in less run off and erosion.

Other soil types, Gleysolic, Miscellaneous and Undefined constituted only a small proportion of the total land area within a given rainfall contour. Except for the Undefined soils within the 125-150 rainfall contour interval, damage density was lower than average damage density. This suggests that these soil types were not as likely to be eroded.

CONCLUSIONS

The analysis could have been improved by including information regarding land use. However this data base currently does not exist at a level detailed enough for this study. Despite these shortcomings, Solonetzic soils were identified as being highly erosion prone. Luvisolic soils showed low values for damage density but were expected to be prone to erosion. This was likely due to the high proportion of Luvisols found under forest vegetation within the study area. Without land use information, the analysis was unable to provide a good indication of the susceptibility of agricultural Luvisolic soils to water erosion.

Chernozems were neither erosion prone nor erosion resistant.

The soil types most susceptible to erosion would be those soils with a shallow surface horizon, underlain by a relatively impermeable subsurface horizon. This analysis indicates that Solonetzic soils are high erosion risk soils and management efforts should focus on protecting these soils from water erosion.

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THE HYDROLOGICAL RESPONSE OF A SMALL WATERSHED ON SOLONETZIC SOIL

D.S. Vanderwel[1] and S.A. Abday[1]

INTRODUCTION

There are 4 to 5 million hectares of Solonetzic soils in Alberta. They constitute approximately 30 per cent of arable land in the province and include the largest area of Solonetzic soils in Canada (Hardy 1984).

Solonetzic soils have properties that affect the way they respond hydrologically to precipitation and runoff. The soils are characterized by shallow topsoil, low organic matter, and prominent development of hardpan in the B horizon. It is the subsurface hardpan, a massive columnar structure which develops within the subsurface horizon that most importantly affects the response of these soils to precipitation.

The ability to provide for runoff prediction and estimation is an important function. Engineers, scientists, and planners utilize runoff estimation techniques for the development of structural works, for water resource management, and for water erosion prediction.

Runoff estimation techniques have evolved primarily in the United States (US). The Curve Number Method is an empirical approach that is derived from the collection of data from many small watersheds in the US (US SCS 1992). The methodology enables the calculation of a runoff volume for a given watershed for a selected storm event. By applying an estimate of 'time of concentration' it is also possible to estimate a peak rate of runoff. The method is used in Alberta by some professionals in the estimation of runoff. It also forms the hydrological basis for comprehensive computer models used in the province to predict and analyse runoff, soil erosion, and sediment and nutrient transport.

The fundamental basis for this runoff estimation method is the "Curve Number". Selection of a Curve Number involves assessment primarily of the soils' hydrological characteristics. Soils are grouped from A to D according to their runoff generating potential. Group D soils are categorized as mostly clays with high swelling percent, but the group also includes shallow soils with nearly impermeable subhorizons near the surface, such as Solonetzic soils.

This paper investigates the hydrological response of a gauged watershed comprised entirely of Solonetzic soil. The Curve Numbers for storms over a 9 year period of record are calculated and compared to runoff curve numbers as published and used by hydrologists throughout North America.

<u>Basin Description</u>

The Riviere Qui Barre (RQB) watershed site is located 11 km north and 13 km east of the City of St.Albert within the Municipality of Sturgeon. It is located at approximately latitude 54 degrees north and longitude 114 degrees west.

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The 12.1 hectare watershed is well drained with clearly defined drainage paths for surface runoff. The topography is hilly with slopes ranging from 4 - 9 %. The drop in elevation from the highest point within the watershed to the point of discharge is 19.70 metres. The maximum estimated flow length within the watershed is 575 metres.

The watershed area was seeded to forage in the early eighties. The land has not been broken since then and is now considered tame pasture. The land is well managed in that it is not heavily grazed, it receives frequent application of manure, and cattle are grazed on a rotational basis.

The watershed outlets into an unnamed intermittent creek which originates near the village of Riviere Qui Barre. The unnamed creek drains to the Riviere Qui Barre which is tributary to the Sturgeon and North Saskatchewan Rivers.

Soils and Parent Material

The soils within the watershed area are Black Solonetz, Duagh Clay developed on Lacustrine material. The till mantle is fine textured lacustrine material. The area is underlain by Edmonton Formation; i.e. upper cretaceous bedrock, a brackish water formation composed of bentonitic sandstones, sandy shales, bentonitic clays, and coal seams. The surface soils are of heavy clay texture and typical of Soloneztic soils are subject to severe cracking.

METHODOLOGY

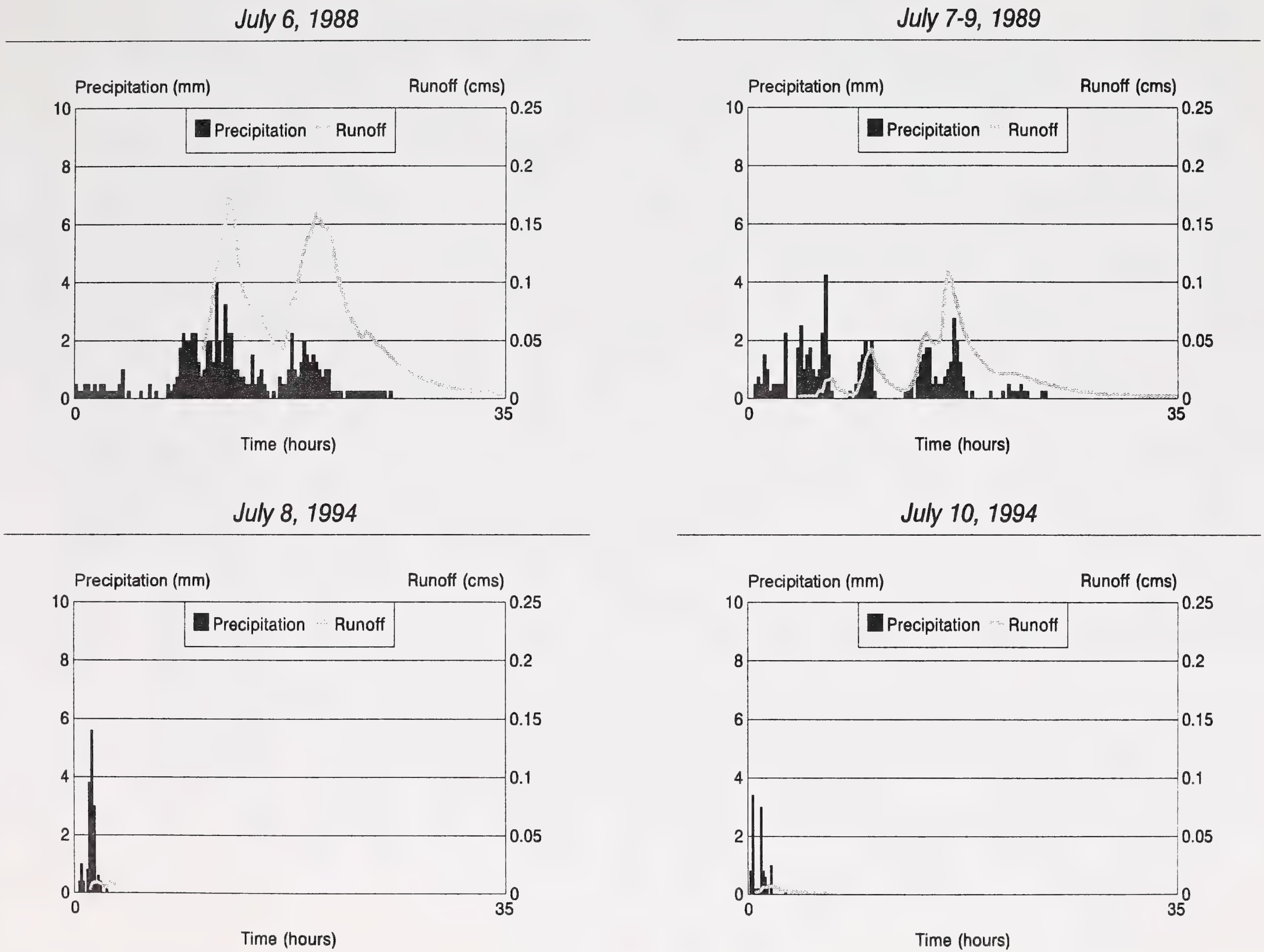
Hydrometric and meteorological monitoring equipment were installed in the autumn of 1987. The purpose of the project initially was to observe the relationship between rainfall intensity and the runoff hydrograph. There were no plans to monitor snowfall and snowmelt. Monitoring equipment was installed each year (1987 - 1994) in May and dismantled in October.

A single tipping bucket rain gauge is used to measure total rainfall, and rainfall intensity. From 1988 to 1991 the Weather Measure Corporation, Model P-501 gauge was used in conjunction with a Model P521-S strip chart event recorder. In 1992 this gauge was replaced by an Ota Keiki Seisakusho Company, Model 34-T rain gauge together with a Campbell Scientific CR10 datalogger.

Hydrometric monitoring is undertaken with a 3 foot H-flume. The rated flow capacity of the flume is 0.9 cubic metres per second. In 1988 a Stevens Type F, model 68, strip chart, level recorder was used. This was replaced by a Stevens Type A-35, stripchart, level recorder in 1989. In 1992 a Steven AF-1 encoder and Stevens AF logger, model 8901 were incorporated into the water level recording system. In 1994 a Campbell Scientific CRIO datalogger was used.

A double ring infiltrometer test was undertaken to determine saturated hydraulic conductivity.

Figure 1. ***Rainfall - Runoff Hydrographs - 1988-1994***



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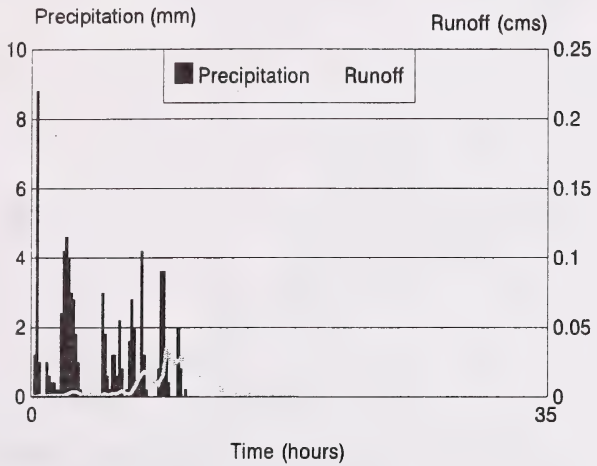

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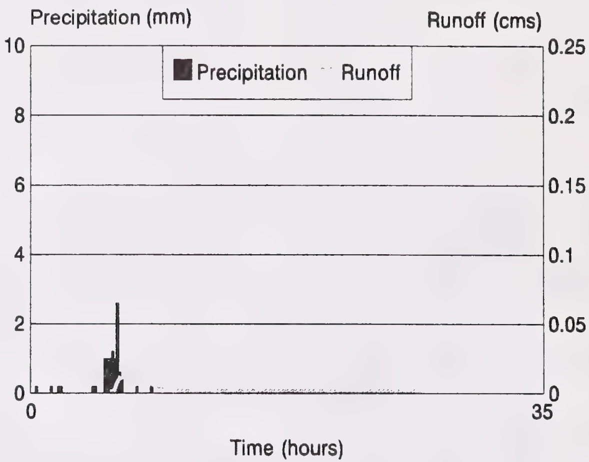

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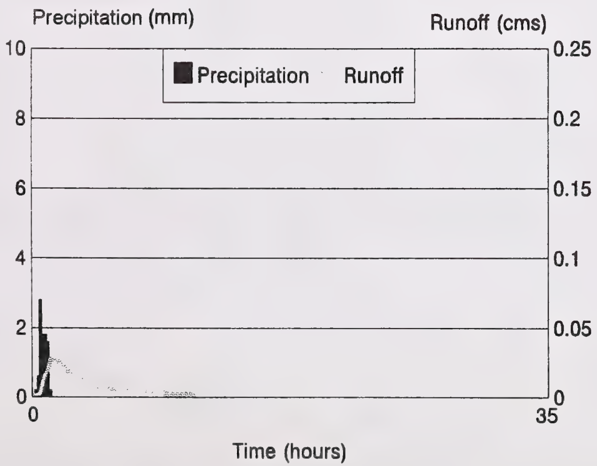

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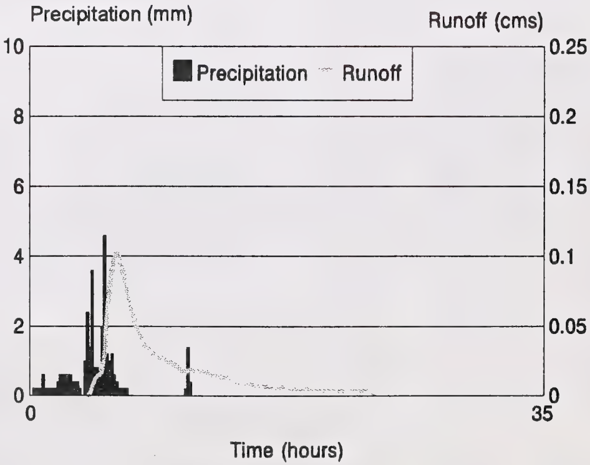

Table 1: Storm Rainfall and Runoff Characteristics (1988-1994)

Storm Date	Total Precip. (mm)	Direct Runoff (mm)	Peak Flow (cms)	Initial Abstraction (mm)	Curve Number (CN)
June 23, 1988	40.9	0			
July 5, 1988	78.25	46.1	.176	13.25	90.8
May 20, 1989	45.5	0			
June 27, 1989	34.0	0			
July 7, 1989	61.25	18.1	.11	10.5	73.5
July 2, 1990	66.0	9.2	.025	n/a	n/a
Aug. 31, 1990	30.4	0			
May 8, 1991	26.5	0			
Aug. 12, 1991	41.8	0			
June 23, 1993	40.8	0			
July 8, 1994	16.6	0.74	.01	12.0	91.3
July 10, 1994	10.6	0.6	.007	4.4	81.7
Aug. 1, 1994	37.4	4.5	.033	8.0	61
Aug. 9, 1994	9.2	1.5	.011	3.0	92.9
Aug. 10, 1994	9.0	2.9	.027	0.5	93.9
Aug. 17, 1994	31.8	12.0	.103	10.6	93.5

DISCUSSION

Since 1988 10 rainfall events have generated runoff from the RQB watershed (Figure 1). The were no runoff events in 1991, 1992 or 1993. This was a period of below normal precipitation in Alberta. The smallest runoff event was generated by a 9 mm storm. Several rainfall events exceeding 40mm did not generate runoff events. Six small storms during the summer of 1994 generated runoff events.

The long term average total precipitation from May to September is 343 mm. In the nine year period of record (1988 -1994) 1988 approached the average condition (335mm) and 1994 exceeded it (383mm). But for the period of record 1989 to 1993 the seasonal precipitation for each of the years was less than the long term average. The total rainfall for 1992 was 141mm.

The surface runoff as a result of the storms are analysed in order to calculate the total runoff Curve Number for each storm. The tabulated Curve Numbers are mostly quite high. Five of the nine storms resulted in Curve Numbers greater than 90. The largest storm (1988) and the smallest storm (1994) both resulted in Curve Numbers greater than 90. The Curve Numbers are high and are equal to or greater than values recommended for Group D soils in fallow and road surfaces (Dickinson).

A review of the nine years of rainfall data shows the importance of antecedent moisture condition of the watershed in relation to runoff. Particularly on the Canadian

prairies which experience varying degrees of soil moisture deficiency on a regular basis, (Dzikowski 1990) this becomes an important factor in the expectation of runoff following rainstorms. Seven rainfall events during the period 1988 - 1994, exceeding 25 mm did not generate runoff events (Table 1.) Four small storms in 1994 less than 25 mm in magnitude did produce small amounts of runoff. The fundamental difference accounting for the production of runoff was not the variation in rainfall intensity, but rather the antecedent moisture condition of the watershed.

Soil structure is also identified as a significant factor in the production of runoff from the RQB watershed in relation to soil moisture condition. Despite the heavy textured clays, with their attendant low infiltration rates, found predominantly within the watershed initial moisture retention is high. Saturated hydraulic conductivity is extremely low, but the watershed is nonetheless able to absorb a large quantity of moisture prior to runoff following dry periods. Observations show that significant soil cracking, and the development of a blocky soil structure in the upper soil profile provide considerable available storage for initial moisture inputs despite the heavy clay texture of the soil. Large cracks extending into the soil profile can intercept runoff as a result of extremely intense rainfall events to the extent that runoff does not become a factor of rainfall exceeding infiltration until the upper soil profile is saturated. At which time the infiltration rate then approaches zero.

Curve numbers for events at the RQB watershed are consistently high. In fact the calculated Curve Numbers for RQB runoff events are as high as those recommended for hard packed road surfaces. The RQB watershed soils are Soloneztic with characteristic impermeable B horizon. Wright and Vanderwel, 1995 identified a relationship between runoff/erosion events and soils exhibiting impermeable subsurface horizons in the Peace Country region of Alberta. The importance of a saturated A horizon prior to a runoff event for these hardpan soils is identified.

Three runoff events resulted in Curve Numbers less than 90. The hydrologic condition could have been excellent as a result of good moisture, heat units, and limited grazing. However hydrologic condition alone would not account for such a great difference. Neither can lower Curve Numbers be explained here on the basis of previous seasonal rainfall or precipitation five days preceding the storm and runoff event.

CONCLUSION

Heavy textured soils may have very low saturated hydraulic conductivity but they can nonetheless offer considerable moisture infiltration if soil structure is such that physical openings in the soil profile in the form of cracks exist.

Soils with impermeable subsoil horizons greatly affect the hydrologic response of a landscape. Antecedent moisture conditions are important in determining the hydrologic response of any watershed but are particularly important in evaluating the response of basins whose soils are comprised of impermeable subsoil horizons. This is especially noteworthy for Alberta where significant soil groups such as Luvisol and Solonetz by their very nature have subsoil horizons that limit infiltration. Where antecedent moisture conditions are dry, large storms deplete this storage before runoff occurs. Similarly for smaller storms, there may not be any runoff unless this available storage is depleted.

Runoff generation for heavily cracked soils with impermeable subsoil horizons is less dependant upon rainfall intensity than it is upon depletion of available surface horizon water

storage.

Based on measured rainfall and runoff at RQB, and calculated Curve Numbers, the runoff volume from Solonetzic and other soil groups with impermeable subsoil horizons can be exceedingly high. These soils must be treated carefully in terms of watershed and field soil management.

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CONSERVATION - FIELD SHELTERBELTS

EVALUATION OF CROP YIELDS ADJACENT TO FIELD SHELTERBELTS IN ALBERTA (1994)

J. Timmermans, G. Nelson and C. Sprout[1]

INTRODUCTION

Field shelterbelts protect soil and crops by slowing wind, trapping moving sand and silt, and decreasing surface-wind sheer stress (Hagen 1976). Shelterbelts prevent wind from stripping seed from soil in the spring and decrease sand blasting of crops by wind-borne sand (Kort 1988). Winds are effected 20H (20 times shelterbelt height) to 30H leeward of shelterbelts and 5H windward of shelterbelts (Hagen and Skidmore 1971; Staple and Lehane 1955). Shelterbelts slow wind most effectively up to 10H (Brandle 1990).

Shelterbelt trees occupy space, and compete with field crops for nutrients (Bates 1911). Studies in Saskatchewan and Manitoba found a positive response of crops to shelterbelts (Pelton 1976; Kort 1987). Research under Alberta growing conditions is necessary to confirm these results.

The objective of this project is to determine the effect of field shelterbelts on crop yields in Alberta. Data collected from this study will be combined with results from Saskatchewan and Manitoba to create a prairie-wide database. This data will be applied to the "WBECON" computer program. "WBECON" was developed to predict economic outcomes for shelterbelt planting alternatives and will be used to help farm operators make informed decisions when planning to plant shelterbelts (Kort and Brandle 1991a and 1991b).

METHODS

In 1994, spring seeded crops were sampled from 70 fields throughout Alberta; 3 hay (alfalfa and grass species) were also sampled. Spring seeded crops sampled included wheat, oats, barley, peas and canola. Samples were taken from Brown, Dark Brown, Black, Grey and Dark Grey soils throughout Alberta. Fields were sampled to the east, west, north and south of field shelterbelts. Sites were selected according to uniformity of crops, soil and topography. Shelterbelt types included poplar, caragana, spruce, elm, mixed and native (multiple native species) trees. Shelterbelts were chosen for uniform height, width and density. Field corners, obstacles adjacent to shelterbelts and other anomalies were avoided when sampling.

Spring seeded crops were sampled along 3 transects perpendicular to shelterbelts. One or 2 square metre samples were harvested using hand-held sickles, at distances of 0.5, 1, 2, 3, 5, 7, 10, 15, 20 and 30H along each transect. Distance measurements began at the centre of the shelterbelt. Samples were placed in cotton bags and cured for 1 to 2 months. Following over-night forced air drying, crops were threshed and weights were recorded.

Yield of spring seeded crops in the sheltered field (0 to 15H) was calculated as a

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percentage of open field (15 to 30H) yield. Differences between mean yields of open field and sheltered area were tested using analysis of variance ($p=0.05$).

Hay samples were collected from cut swaths, weighed and returned. Subsamples were collected and placed in plastic bags to determine moisture content. Dry matter weights were analyzed using Duncan's multiple range testing. Hay fields were few, and the results quite variable. The results are not reported here.

RESULTS AND DISCUSSION

Relative yields of all spring seeded crops sampled averaged a negative one per cent (STDS $\pm$ 15) in the sheltered zone compared to open field. Of the 66 fields used in the analyses (four were highly variable due to factors other than the shelterbelts, and therefore not included), 25 had average sheltered yields greater than open field yield. Crop yield increases in the sheltered portion of fields were lower than those reported previously throughout the prairies (Timmermans et al. 1994; Kort 1985; Kort 1987; Pelton 1976; Staple

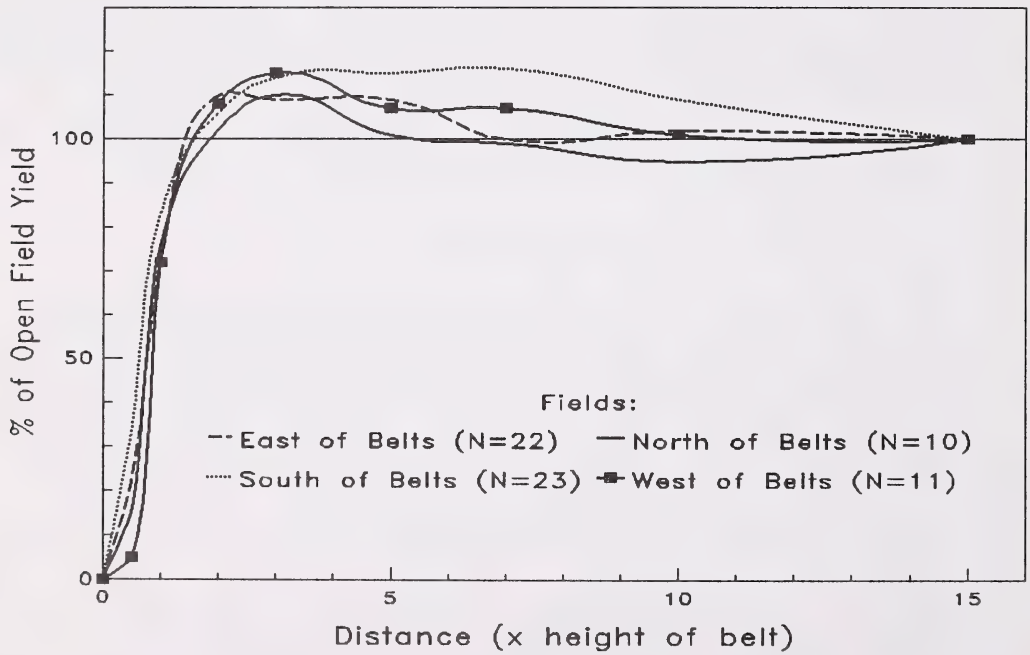

Figure 1. Crop yields adjacent to field shelterbelts in 1994.

and Lehane 1955).

Snow accumulations in Alberta were below average between January and April, 1994 (Dzikowski 1994). Moisture trapped in snow drifts by shelterbelts can improve crop yields (Stoeckeler 1962). Weather conditions including wind and falling or drifting snow resulting

in substantial drifts behind shelterbelts did not occur. No relationship between spring soil moisture and crop yield response was noted for the 1994 growing season.

In 1994, crops south of E-W oriented shelterbelts appeared to show the strongest yield response, and crops north of E-W belts the least (Figure 1). There was a trend for relative yield to increase from 2H to 7H and to decrease towards open field (15H to 30H).

Figure 2 shows response of canola, wheat and barley to shelter in 1994. Canola

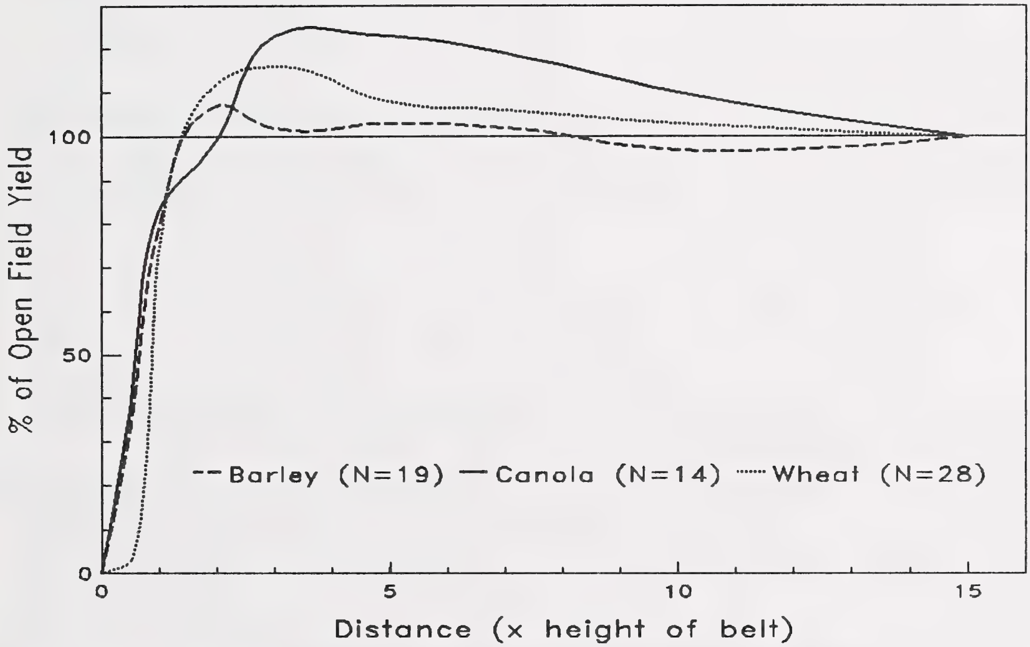

Figure 2. Effect of field shelterbelts on yields of adjacent canola, barley and wheat crops in 1994.

appeared most responsive to shelter. *Brassica spp.* (canola) are among crops reported less tolerant to wind exposure than cereal crops (Finch 1988). Table 1 shows the relative sheltered yield of peas, wheat, canola and barley. Results indicate that the yield response by canola was greater than other crops in 1994.

Figure 3 outlines crop response to shelterbelts on Brown, Dark Brown, Black and Grey soils. Sheltered crops in the Brown soil zone tended to have a higher relative yield than sheltered crops growing in other soils. Relative yield response in the Brown soil zone may be correlated to the many caragana shelterbelts in that zone.

Relative yields adjacent to caragana were higher than relative yields adjacent tall deciduous (poplar, elm and willow) and multirow shelterbelts (Table 2). Yield trends for tall deciduous, mixed shelterbelts (single row belts with more than one tree type per row), spruce and multirow shelterbelts imply lower sheltered yields compared to open field (Table 2), but because the starting distance of 0H was the center of the shelterbelt, wider belts than single

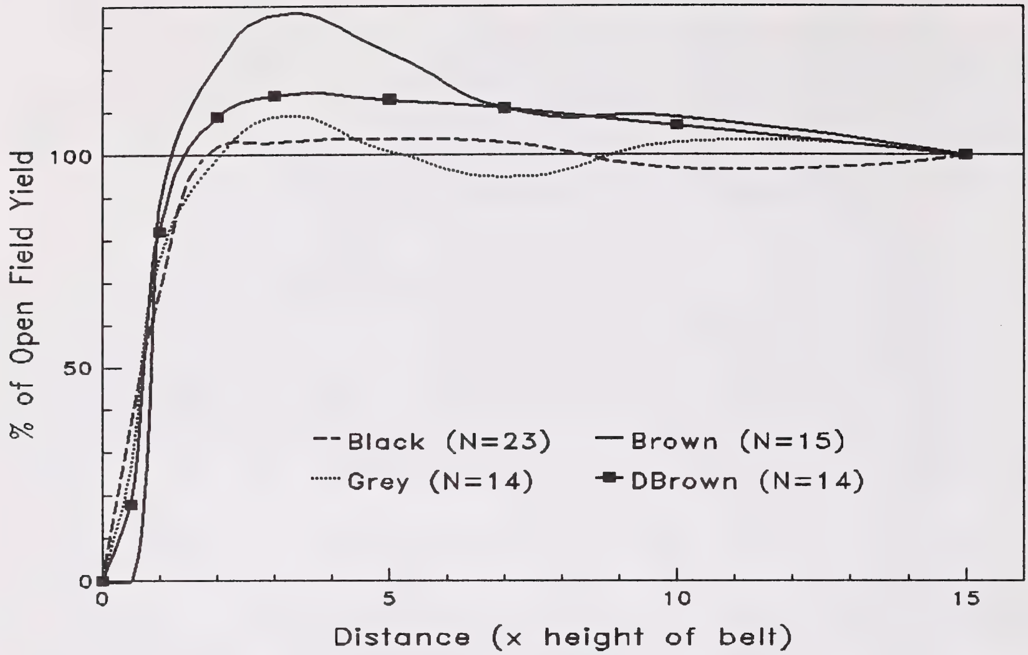

Figure 3. Effect of field shelterbelts on crop yields on Brown, Dark Brown, Black and Grey soils in 1994.

Table 1. The effects of field shelterbelts on peas, wheat, canola and barley yields in 1994.

Crop	N	Average Sheltered Yield (%)†
Peas	4	96
Wheat	28	99
Canola	14	106
Barley	19	95

†Sheltered yield is the relative yield of the area 0 H to 15 H taken as a percentage of open field.

row would show a larger zone of no yield. Furthermore, many of the multi-row or native belts included poplar. This shallow rooted tree is also more competitive with the crops, for moisture and nutrients.

Table 2. Shelterbelt types and their effect on crop yields is 1994.

Shelterbelt Type	N	Average Sheltered Yield (%)†
Caragana	31	105 A
Tall Deciduous	9	92 B
Mixed	8	96 AB
Multi-row	10	95 B
Spruce	2	99 AB

†Sheltered yield is the relative yield from 0H to 15H taken as a percentage of open field yield.
Average sheltered yield values followed by the same letter are not significantly different (P=0.05)

CONCLUSIONS

Higher crop yields in the zone influenced by field shelterbelts compensated for the land yield loss in the area occupied by trees, and in the zone of competition (negative one per cent in the zone of 0 to 15H). The variables of soil zone, crop type, width and type of shelterbelt, and direction from shelterbelt all influenced these results.

Results from this study will be applied to the "WBECON" computer program to increase accuracy of that model when used by Alberta farmers. Information produced from this study is necessary to promote soil conservation through the knowledge of how trees benefit crops. Alberta based research is required to encourage shelterbelt planting in this province. More years of research are required to build a reliable data base which will help farmers plan and implement shelterbelts in Alberta.

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WIND REDUCTION BY A GREEN ASH SHELTERBELT

J. Timmermans, C. Sprout, G. Nelson[1]

INTRODUCTION

Field shelterbelts can be an effective component of farm conservation management. Shelterbelts are a barrier to erosive winds, they trap snow, and provide shelter and habitat for wildlife. The reduction of wind velocities by shelterbelts results in altered conditions in the zone of influence. Drifted snow can result in the positive effect of greater soil moisture supply for crop growth. Drifted snow can also result in delays in field operations in spring and fall when the extra moisture has slowed the drying in spring, and delayed crop maturity at harvest time.

In previous studies, (Timmermans et al. 1992 and 1993), wind reduction by caragana was measured, both in-leaf without leaves. This study was undertaken to similarly assess reduction of wind velocities by a single row green ash shelterbelt.

METHODS

The green ash shelterbelt used in 1994 is located near Carbon, Alberta on a gently rolling Dark Brown Chernozemic clay (NE Sec. 19-28-22, W4). The shelterbelt is an E-W single row. It is 20 years old, with the trees spaced at 3 m. The trees were 4 m tall, and 4.5 m wide. The trees were healthy and in full leaf but there were some gaps due to missing trees. There are other shelterbelts to the north and south at about 160 m from the green ash shelterbelt. The field directly to the south of the green ash shelterbelt was in fallow in 1994 and this provided an opportunity to set up and monitor the wind speed sensors from August 3, to October 13, 1994 without causing crop damage.

The monitoring equipment consisted of an array of seven Campbell Scientific Model 014A Met-One anemometers placed in a line perpendicular and to the south of the shelterbelt. The spacing of the anemometers was a factor of the height of the shelterbelt (H) as follows: 1H, 3H, 5H, 7H, 10H, 15H, 20H. The 20H location was assumed to be out of the range of influence of the shelterbelt and therefore represents the open field or unsheltered value. A wind direction sensor was placed at 20H, temperature and relative humidity sensors were installed at 3H and 20H. The 3H location was considered to be near the most sheltered distance from the shelterbelt. All sensors were set up at a height of 1 m, except the wind direction sensor which was placed at a height of 2 m. All sensors were connected to a datalogger programmed to register an input every 30 seconds, calculate and store an average every 10 minutes.

Wind reduction or relative wind speeds at the different distances were calculated by dividing those velocities by the corresponding one at 20H. The wind direction as measured in degrees was grouped into 16 segments of the compass, each segment included 22.5°. Combined winds include NW, NNW, N, NNE, and NE winds ($90 \pm 56.25°$). The relative

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wind speed averages used in the statistical analyses excluded all values where the wind speed at 20H was less than 0.5 m s^{-1} (1.8 kmh), which is the threshold value of this anemometer.

RESULTS

Figure 1 shows relative reduction of windpeeds leeward and perpendicular to the belt (±56.25°). The greatest wind reduction occurred when the wind was perpendicular to the

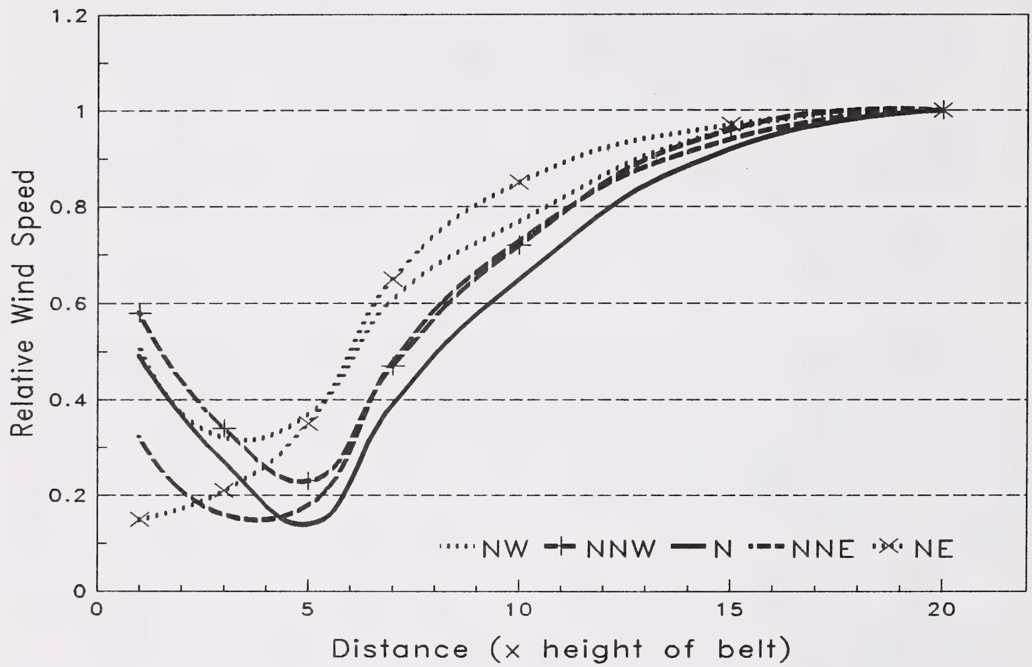

Figure 1. Relative wind speeds from different directions leeward of an E-W in-leaf green ash field shelterbelt.

shelterbelt from the North (90 ± 11.25°). The wind reduction is apparently less, of winds from the NNW and NNE and less still, of the NE and NW winds. While the protected distance when measured perpendicularly from the belt is reduced, the distance from the shelterbelt to the recording instrument is greater when measuring reduction in velocities of oblique winds.

Figure 2 shows the average results of the effect of in-leaf and out-of-leaf green ash and caragana shelterbelts on leeward wind speeds. The data for the caragana shelterbelts is from a previous project. It is evident that both green ash and caragana shelterbelts are effective at reducing wind velocity when in-leaf, particularly in the 1H to 7H area. The maximum wind reduction for green ash in-leaf is 74% at 3H to 5H compared to caragana in-leaf with 77% at 3H. The distance to 90% recovery of open field velocity is 13.5H for in-leaf green ash compared to 17.5H for caragana in-leaf. As would be expected, the out-of-leaf shelterbelts

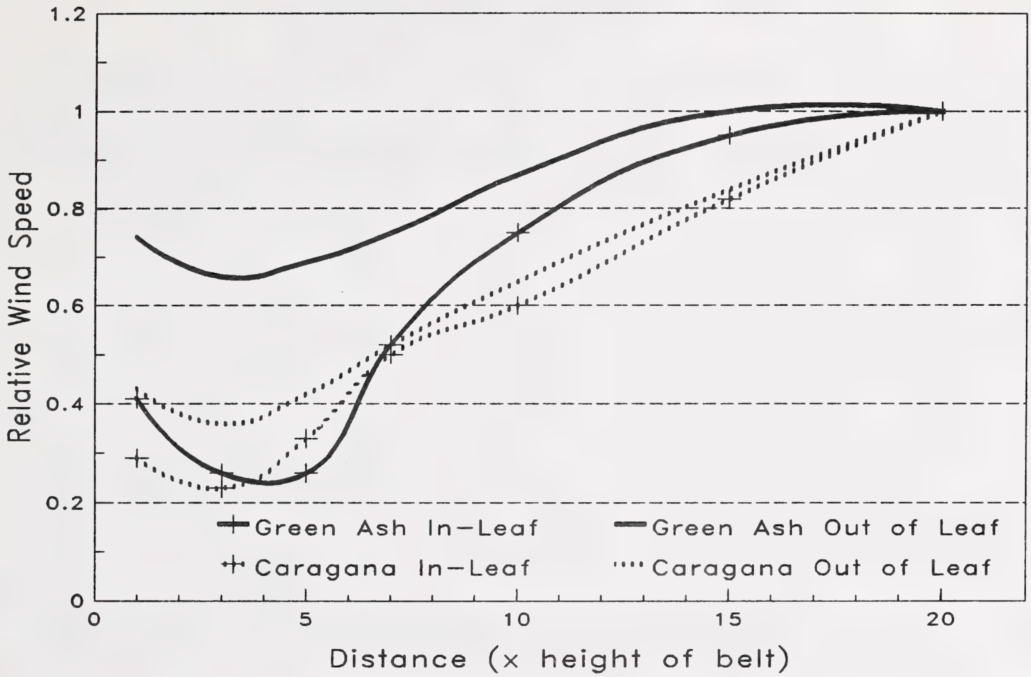

Figure 2. Relative windspeeds leeward of caragana and green ash shelterbelts, in and out of leaf (winds measured were from the north ± 56.25°)

reduced the wind velocities less than when in-leaf. Green ash showed only a 33% maximum reduction at 3H for the out-of-leaf shelterbelt as compared to the caragana out-of-leaf which had a 64% reduction at 3H. The distance to recovery was 11.5H for green ash out-of-leaf compared to 17H for caragana out of leaf. Caragana is still very dense even without leaves, compared to green ash which provides very little obstruction to the wind when it is out-of-leaf.

Table 1 lists the mean relative wind speeds for all north winds and for north winds greater than or equal to 4.5 m s^{-1} (16.2 kmh). This allows for a comparison of how wind velocity can affect the wind reduction leeward of a green ash shelterbelt. The numbers show that in the 1H to 7H area there was about 16% less wind reduction when higher wind velocities only are used as compared to an average of all wind speeds. The protective distance (90% recovery of open field velocity) is the same but near the shelterbelt wind reduction is not as effective with higher velocity winds.

The air temperature and relative humidity measurements were compiled to produce daytime (8 am - 8 pm) and night-time averages for the sheltered (3H) and unsheltered (20H) locations. The average results are for the in-leaf green ash shelterbelt and are shown in Table 2. The sheltered location consistently produced significantly higher temperatures than the unsheltered location. As expected the largest differences are with the daytime north winds. The higher temperatures in sheltered area may provide more heat units for growing crops. There was no significant difference in relative humidity between sheltered and unsheltered

Table 1. The effect of wind velocity on wind reduction leeward of an in-leaf green ash shelterbelt.

Distance	Mean Relative Wind Speeds		
	All North Winds	North Winds ≥4.5 m s^{-1}	Difference
1H	.41 E	.58 E	.17
3H	.26 F	.42 F	.16
5H	.26 F	.46 G	.2
7H	.52 D	.61 D	.09
10H	.75 C	.76 C	.01
15H	.95 B	.95 B	0
20H	1.0 A	1.0 A	

Relative wind speeds followed by the same letter within columns are not significantly different (P≥0.05).

Table 2. A comparison of temperature and relative humidity for sheltered and unsheltered locations behind an in-leaf green ash shelterbelt.

Parameters	Temperature °C		% Relative Humidity	
	Sheltered	Unsheltered	Sheltered	Unsheltered
Daytime All Winds	15.50 A	14.97 B	62.43 A	62.69 A
Daytime North Winds	15.66 A	15.03 B	70.05 A	70.87 A
Night-Time All Winds	11.65 A	11.25 B	74.33 A	74.38 A
Night-Time North Winds	11.89 A	11.65 A	85.51 A	85.56 A

Temperature or relative humidity values followed by the same letter within rows are not significantly different (P≥0.05).

locations, but the trend shows lower relative humidity in the sheltered area.

CONCLUSIONS

Single row caragana, both in-leaf and out-of-leaf are more effective at reducing wind velocities, than the more porous green ash. The caragana and green ash shelterbelts reduced wind speeds by 77% and 74%, respectively, in-leaf. In contrast, the maximum wind speed reduction of was 64% and only 33%, respectively, when out-of-leaf. The multi-stemmed nature of caragana when compared to the very open nature of green ash in winter is the reason for this difference.

The above comparison points out the importance of species selection in designing field shelterbelts. For some farmers, maximum windspeed reduction is a goal, because the greater the reduction, the larger are the drifts of snow trapped by the shelterbelt. For others, a deep snow drift is a negative result, because extra moisture in spring can result in delayed soil preparation and seeding, delayed swathing, and harvest in fall. A more porous shelterbelt such as green ash in winter and early spring will result in more uniform accumualtion of snow than a dense belt like caragana.

The effect of the green ash shelterbelt on the microclimate in the lee of the shelterbelt did not appear to be great. Temperatures were consistently higher in the sheltered area but only slightly so. There was no significant difference in relative humidity between sheltered and unsheltered locations.

Future research will provide similar data on other types of shelterbelts to produce a larger database of information upon which recommendations on shelterbelt design can be made.

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WATER QUALITY

INTEGRATING LARGE AGRICULTURAL DATABASES TO SELECT WATER QUALITY MONITORING SITES

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INTRODUCTION

Agricultural Pollution Issues In Alberta

Agriculture has been identified as the leading source of water quality impairment of U.S.A. rivers and lakes by the United States' Environmental Protection Agency (1994). Agriculture in Alberta is predominately extensive not intensive and the use of fertilizers, herbicides and insecticides in Alberta are low compared to other areas of North America (Paterson and Lindwall 1992). Consequently, preliminary research in Alberta did not find the degree and extent of water quality degradation as in other parts of North America. Anderson et al (1991) monitored the Battle River and found concentrations of seven of the ten best selling herbicides or insecticides were at least a hundred times below the Canadian water quality guidelines (Environment Canada 1994) for the protection of freshwater aquatic life and drinking water. Shaw (1991) sampled 142 wells in shallow aquifers in Alberta and found traces of phenoxy acid herbicides or neutral herbicides (triallate and trifluralin) in only four of 165 water samples. Goatcher et al (1991) concluded that water quality problems in watercourses next to four Alberta feedlots were generally short-lived, restricted and site-specific.

However, Rodvang et al (1992) sampled for herbicides in shallow groundwater below irrigated fields at Lethbridge and identified diclofop-methyl at levels significantly above drinking water guidelines (130 mg/L compared to 9 mg/L). Riddell and Rodvang (1992) found nitrate concentrations above the 10 mg/L maximum for drinking water in shallow groundwater, 3 m deep below irrigated fields where manure spreading exceeded recommended rates. Sosiak and Trew (1994) identified manure contaminated snowmelt from cow/calf wintering sites as the principal source of over 30% of the annual phosphorus load in Pine Lake in 1992. The Anthony Henday Water Treatment Plant (Town of Innisfail) had serious water problems at snowmelt in 1994 that were linked to cattle watering and wintering sites along the Medicine and Little Red Deer rivers. The Alberta Cattle Commission (1994) headlined the issue in their June newsletter and held seminars with cattle producers along these rivers.

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METHOD

Selecting Landscape Units For Surface Water Quality Monitoring

Under the Canada-Alberta Environmentally Sustainable Agriculture (CAESA) agreement, the CAESA Water Quality Monitoring committee has the task of defining agriculture's impacts on provincial water quality. The Surface Water Quality subcommittee of CAESA concluded that agricultural contamination had more implications for small tributaries and lakes than other surface water bodies (Cross et al 1994). Funding limits meant that the subcommittee focused on finding a representative small watershed that typified water erosion, runoff processes and agricultural production practices for much of Alberta. Field plots do not represent farm-scale processes that deliver contaminants off the farm to surface water bodies.

The subcommittee focused on finding cow/calf wintering sites as part of the representative watershed (Cross 1994). The working group assumed that if a farm-scale watershed was to represent processes typical across the province, three criteria had to be met:

a. The selection process would identify sites that were representative of runoff and water erosion processes in agricultural landscapes of Alberta.
b. The landscapes must deliver runoff from the farm watershed to defined watercourses (e.g. creeks).
c. These sites would have high agricultural inputs (fertilizers, herbicides and livestock numbers).

In summary, the sites would be small agricultural watersheds, representative of water erosion processes delivering sediment and agricultural contaminants to flowing water with potential contaminants in sufficient concentration that they can be detected and measured.

Integrating Agricultural Data Bases To Search For Landscape Units

In Phase 1 of this process, Snowy Owl Software (1993) demonstrated that large scale data bases could be integrated and displayed graphically to represent areas of more intense agricultural production. Figure 1 illustrates, for 1991 on a municipal basis, that creeks and lakes in the Edmonton-Calgary corridor may have larger amounts of phosphorus applied to farmland in their watersheds than creeks and lakes in other municipalities.

In Phase 2, this capability was focused on smaller areas inside municipalities through a new data base from Agriculture and Agri-Food Canada that integrated 1991 agricultural census data with soil landscape polygons (Shields et al 1991). The polygons contain landscapes that have similar soils, landscape features and climate.

Soil/Landscape/Census Characteristics To Select SLC Units

A critical stage in developing criteria for selecting soil landscape units was Wright and

Vanderwel's investigation (1994) of a major water erosion event in July, 1990 in the Peace River region near Grande Prairie. They found that the rainfall events and the soil characteristics that result in off-farm flows carrying eroded soil are not identical to the in-field loss processes most soil researchers have investigated. For example, the 1990 rainfall event near Grande Prairie was a long-duration storm that in a three day period produced 95.7 mm of rain. Most in-field erosion events are driven by high energy, short duration rainfall from thunderstorms. The severity of erosion, i.e. the volume of the gullies, could not be correlated to the size of the watershed, its slope or length. Wright and Vanderwel suggested that other factors were likely more important. Their list of factors are:

1. Soil Development: Soils with a restrictive sub-layer, the A_e or B_t horizon in a Grey Wooded soil or the B_n horizon of a Solonetzic soil, were prone to serious erosion during a long duration storm. While their surface layers had rapid infiltration, once the upper profile was filled with water, the relatively impermeable subsurface layer forced overland flow, setting up the soil erosion event.
2. Soil Texture: Fine textured soils (clays and clay loams) typically were found at eroded sites. Restricted infiltration forced overland flow with a long duration storm.
3. Well Developed Natural Drainage: Once overland flow began, well developed natural drainage channelized the flow, developed gullies and delivered sediment loaded runoff off the farm.
4. Slope: The length of the slope was just as important as the percent slope. Slopes of 2-7% were judged to be erosion prone.

Wright and Vanderwel's factors were the basis for a combination of queries to search the Soil Landscapes of Canada (SLC) data base (Shield et al 1991) for landscape units that would be prone to water erosion under Alberta conditions and practices. Figure 2, SLC Units Selected for Sediment Delivery Potential, represents the soil landscape units that met these criteria.

The SLC data base included census information organized in the soil landscape polygons. In building queries to the census portion of the SLC data base, the surface water subcommittee assumed that barley and canola production dominated cultivated crops. Also, high expenditures on fertilizer and herbicides were assumed to represent high inputs and intensive cropping. Other research projects focused on manure impacts from intensive livestock operations so the committee focused on finding landscapes with cow/calf wintering sites.

The selection process of SLC landscape polygons began afresh by selecting landscape units that were in the top 25% of the province in fertilizer and agricultural chemical expenditures plus in the top 25% of calf density on forage land (intensive cow/calf operations). Figure 3, SLC Units Selected for Agricultural Input Intensity, was the sum of these queries. Figure 3 represented intensive mixed farming with a livestock bias towards beef cow-calf production (MacAlpine 1994).

The final step was to select landscape units that were representative of erosion/runoff potential and also were representative of intensive mixed farming. Figures 2 and 3 were combined and overlapping landscapes were selected. Figure 4, Final SLC Units Selected with All Criteria Applied, shows eleven landscape units in the province that should be representative of typical water erosion risks for Alberta farmland. The eleven units were in water sorted landscapes that had heavy textured soils with well developed natural drainage. They have agricultural production in the top 25% for annual cropping and cow/calf intensity.

The eleven landscapes represent a wide area of the province, from Peace River to Lloydminster to Calgary. Most are located in areas of Black Chernozemic soils since these soils represent the best compromise between heat and moisture in Alberta. Consequently, the most intensive rain-fed agriculture happens on these soils. No landscape units were selected in the irrigated areas because the erosion/runoff selection process orientated the search away from landscapes typically under irrigation.

RESULTS

Final Selection Of a Watershed

The Haynes Creek watershed, east of Lacombe, was selected for monitoring. Environment Canada has a hydrometric station on Haynes Creek. The natural drainage is well defined with minimal natural storage and the watershed is narrow. As a result, individual farm impacts on the creek can be reasonably well defined step by step down the creek. Farms have good soil and water management with many grassed waterways and tree shelterbelts in the upper basin. Oil and gas activities are not intense in the watershed. There are no urban influences and rural residential subdivisions are limited. Intensive farm operations were not a criterion for selection. However, a Hutterite colony with dairy cows, hogs and beef cattle and a small feedlot are located on the creek downstream of the principal monitoring area. Farm managers are cooperative and field installation of monitoring equipment took place in October 1994.

CONCLUSIONS

Determining whether agriculture in Alberta has an impact on water quality will focus attention on monitoring projects like Haynes Creek until the conclusion of the CAESA agreement. However, recent water quality problems related to poor manure management illustrate that the agriculture industry must be pro-active in educating producers to deal constructively with the manure from their livestock operations. Interest in livestock expansion makes the relationship between water quality and manure management an important planning issue for Alberta's municipalities as well. The selection process that led to Haynes Creek is a powerful tool for evaluating environmental issues in relation to agricultural activities. The ability to integrate large databases and present the results graphically as detailed maps provides an analytical capability not matched by most

Geographic Information Systems (GIS). Audiences find the maps easy to understand even if the queries to the databases are complex. This process will likely be used to extrapolate findings from the Haynes Creek Study to a provincial scale.

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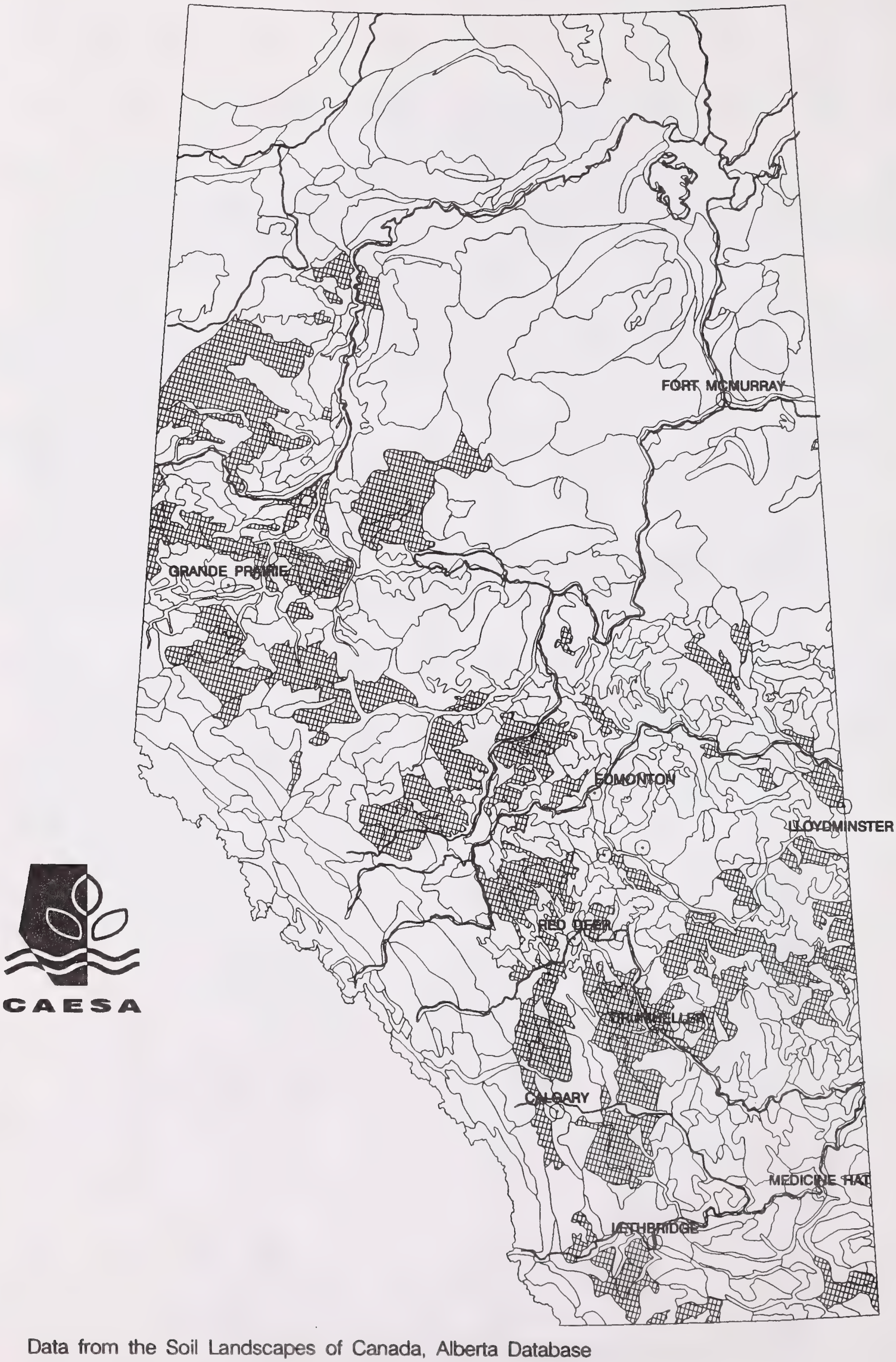
Figure 1. Phosphorus from Manure and Purchased Fertilizer, by Municipality, 1991

Total Phosphorus calculated as P (Purchased Fertilizer) + P (Freshly Excreted Manure), 1991

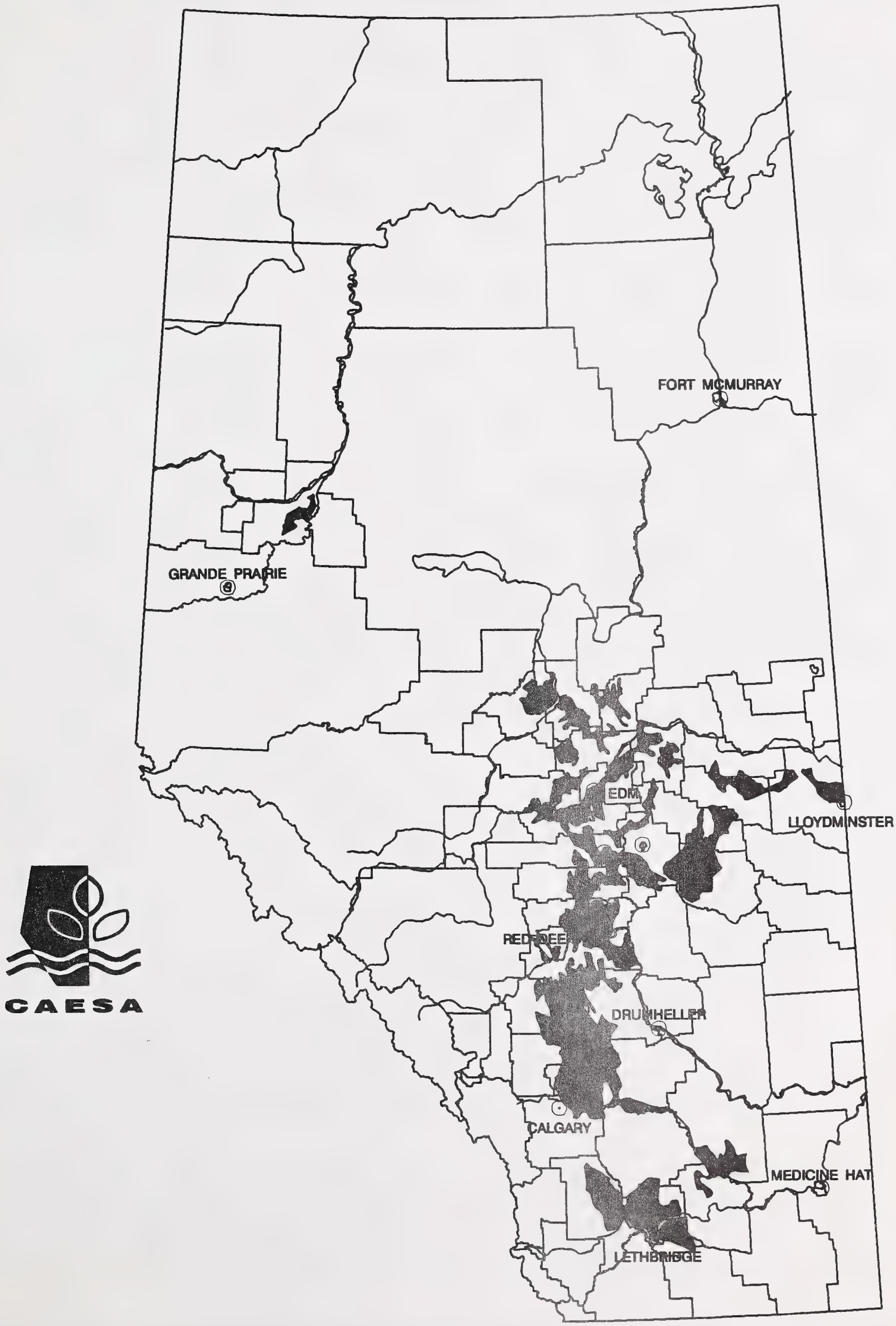
Figure 2. SLC Units Selected for Sediment Delivery Potential.



Data from the Soil Landscapes of Canada, Alberta Database

Figure 3. SLC Units Selected for Agricultural Input Intensity.

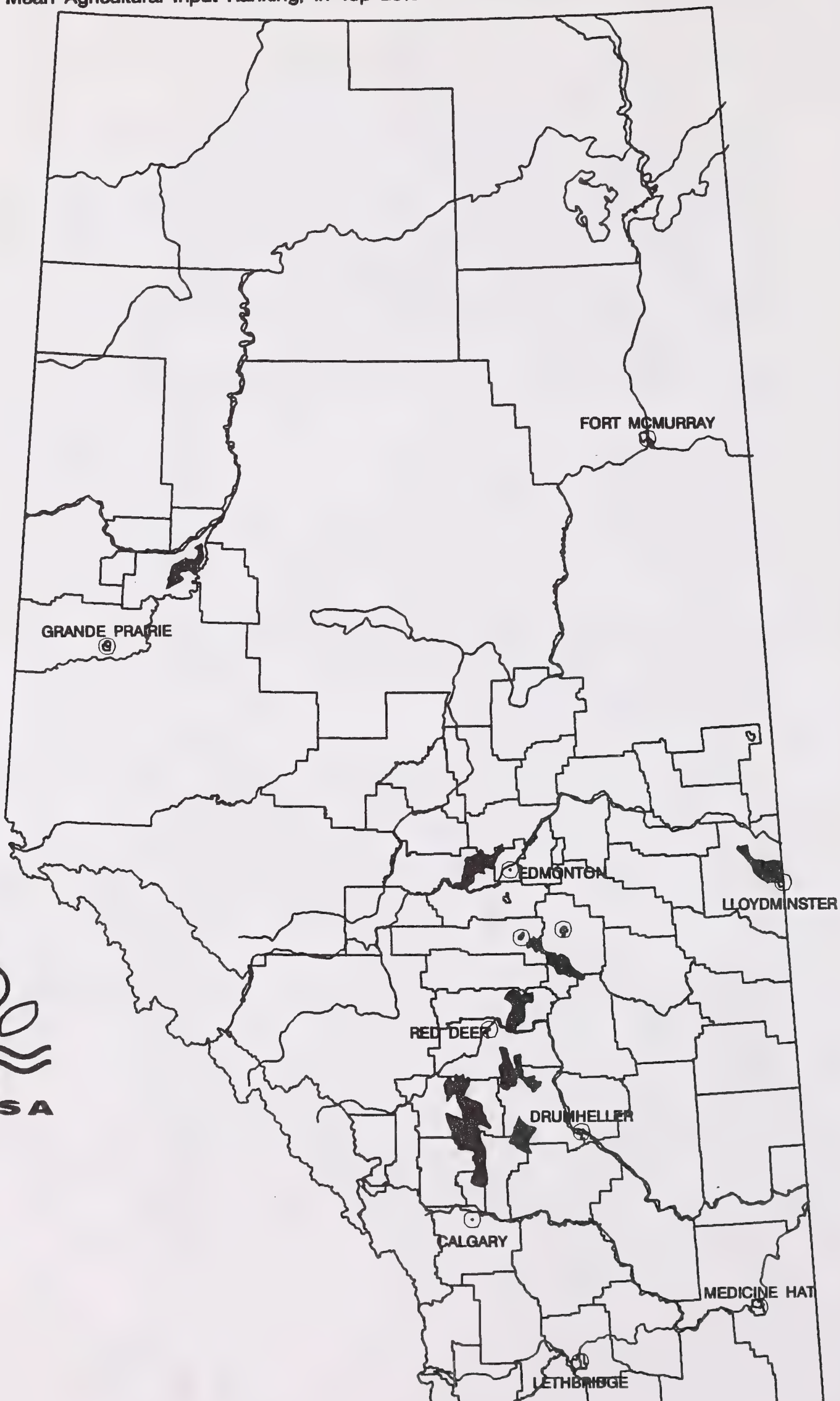
SLC is in top 25% of fertilizer expenses, chemical expenses and calf density



Data from the Soil Landscapes of Canada, Alberta Database

Figure 4. Final SLC Units Selected, With All Criteria Applied.

**Combination of SLC Units Selected by Landscape and Selected by Census Data.
Mapped by SLC. Mean Agricultural Input Ranking, in Top 25%**



CAESA

Data from Soil Landscape of Canada Census (1991) and from the Soil Landscapes of Canada, Alberta Database.

AGRICULTURAL NON-POINT SOURCE POLLUTION MODELS: VALIDATION FOR USE IN ALBERTA

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INTRODUCTION

Pine Lake is a small lake located in central Alberta, Canada. It is intermittently stratified (mean depth of 5.3 m), eutrophic (mean summer chlorophyll *a* concentration of 26 μg/L, mean summer total phosphorus concentration of 56 μg/L) and is fresh (total dissolved solids of 450 mg/L). It is situated in a large watershed with a watershed to lake area ratio (A_{basin} : A_{lake}) of 39. The lake is used extensively for recreational purposes, is popular for sport fishing but has cyanobacterial blooms. Lake users conviction that water quality was deteriorating led to a lake restoration study in 1992. Investigations focused on locating and quantifying sources of phosphorus. Manure runoff at snowmelt from small livestock wintering sites next to creeks was the principal source of 33% of the annual external phosphorous load to Pine Lake (Figure 1). Internal sources in the lake, bottom sediments predominately, supplied approximately 60% of the annual load (Sosiak and Trew, 1994).

Some Alberta lakes are naturally eutrophic because of internal releases of phosphorus from lake sediments. In addition to this source, Pine Lake also receives significant loads from human activities (Figure 1). Pine Lake has extensive shoreline development with cottages and commercial resorts but the 1992 monitoring showed that the agricultural loadings in creeks are larger than even the theoretical maximums from human sewage. If agricultural loadings are not reduced, Pine Lake may continue the trend towards higher cyanobacterial production and poorer recreational quality.

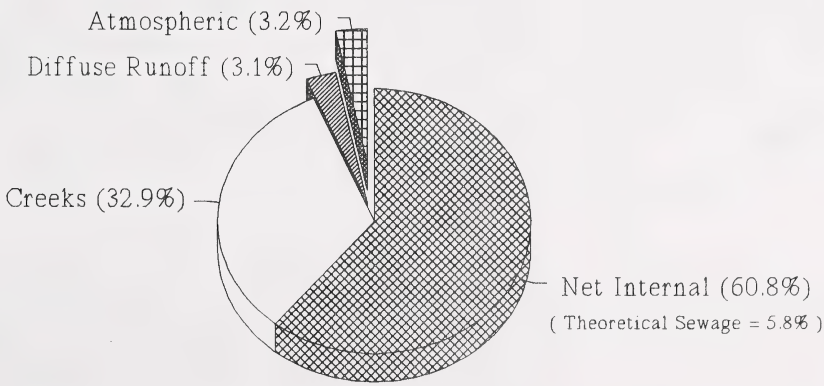

Figure 1 Sources of the total phosphorus budget for Pine Lake (1992).

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The Pine Lake basin does not have intensive agriculture. Small cow/calf operations (50 to 250 head), and a 500 ewe sheep farm were the critical areas for phosphorus loads at snowmelt. Only 26% of the watershed is cultivated for small grains and oilseeds. Pasture (33%) and bush (30%) cover the rest of the 156 km^2 watershed. The knob and kettle landscape permits only 72% of the watershed to drain. The difference between the gross and the effective drainage area of the basin was a significant factor in modelling the watershed's hydrology (Table 1).

Pine Lake's climate is semi-humid continental. Average daily temperatures in 1992 ranged from -35°C in winter to 31°C in summer. Mean annual precipitation is 500 mm (1940-1992). In 1992, precipitation was 444 mm and there were only three rainfall events (May 29, 30 mm; June 12, 27 mm; and September 5, 27 mm) exceeding 25 mm (equivalent to a 1:1 year storm) (Figure 2). Because there were no significant storms, summer runoff events in 1992 were small. In Pine Lake, as in most of Alberta, the effects of spring snowmelt sometimes extend until the end of May. In 1992, approximately 80% (Sub-basins 4 and 7) to 90% (Sub-basin 3) of the observed discharge occurred before July 1, compared to less than 50% of the annual precipitation.

The watershed's soil textures are predominately sandy loams and loamy sands associated with the glacial meltwater channel in which Pine Lake lies. Upland glacial till loams and clay loams have developed under grassland and aspen bush. Saturated hydraulic conductivities (K_{sat}) were estimated as 100 to 300 mm/h in Agriculture and Agri-Food Canada's soil database but were judged too high after initial model runs. Estimated K_{sat} values were calculated from (Savabi, 1993):

$$K_{sat} = \frac{12.7(100 - \%\,Clay)}{(100 - \%\,Clay) + e^{11.45 - 0.097(100 - \%\,Clay)}} \qquad (1)$$

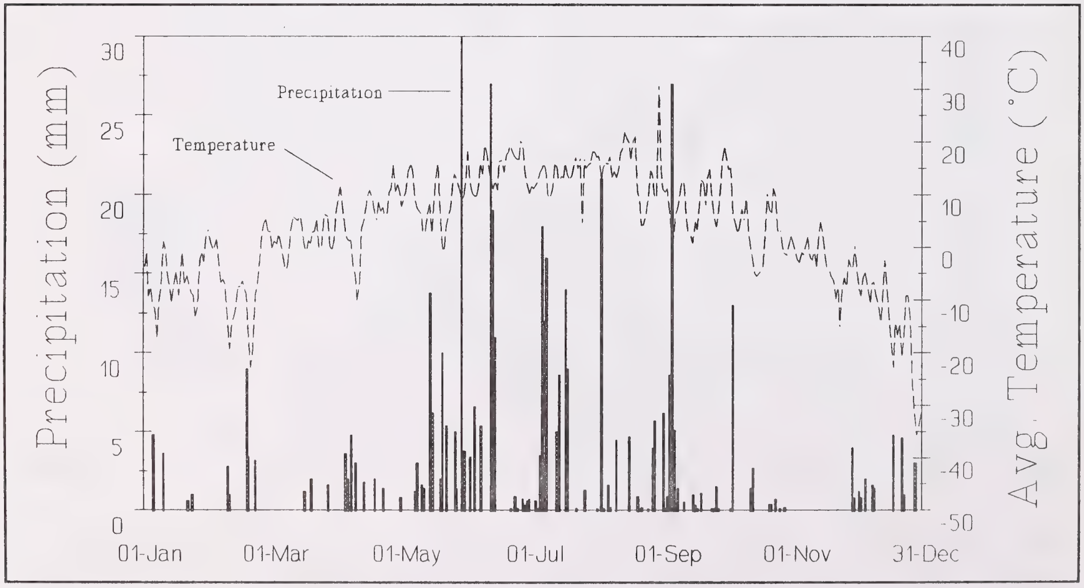

Figure 2 Daily precipitation and average temperatures of Pine Lake watershed (1992).

Table 1 Description of Pine Lake and its drainage basin

The Lake	
Surface Area	3.98 km^2
Maximum Length	6.4 km
Maximum Width	0.8 km
Average Depth	5.3 m
Maximum Depth	13.2 m
Volume	24 087 620 m^3

The Drainage Basin

Area	*Total Area (km^2)*	*Effective Drainage Area (km^2)*	*Sloughs (km^2)*	*Land Use (%)*				
				Bush	*Pasture*	*Hay*	*Cultivated*	*Other**
Sub-basin No. 1	65.20	43.91	13.17	37.05	46.97	3.63	10.17	2.18
Sub-basin No. 2	8.00	5.25	1.69	13.46	44.23	1.92	40.39	0.00
Sub-basin No. 3	11.72	8.54	1.68	15.79	23.68	18.42	42.11	0.00
Sub-basin No. 4	12.20	10.36	1.92	22.50	7.50	5.00	65.00	0.00
Sub-basin No. 5	20.43	15.35	2.92	17.54	12.13	22.01	47.95	0.37
Sub-basin No. 6	7.61	5.64	1.25	26.30	26.82	19.79	26.04	1.04
Sub-basin No. 7	6.44	4.53	0.95	64.29	23.81	11.90	0.00	0.00
Direct to lake	17.13	--.--	--.--	--.--	--.--	--.--	--.--	-.--
No Outlet	3.21	--.--	--.--	--.--	--.--	--.--	--.--	-.--

* includes land uses such as farmsteads and gravel pits

The Pine Lake watershed and its land use are typical of central Alberta lakes. The impact of poorly located cow/calf wintering sites along creeks, rivers and lakes in other parts of Alberta is now being questioned. Calibrating watershed-scale water quality models is an efficient method to transfer what has been learned at Pine Lake to other lakes/watersheds.

Sub-basins 3 and 4 were selected for modelling. They had the highest percentage of cultivated land in combination with the wintering sites identified by Sosiak and Trew (1994) as critical areas. Sub-basin 7 was selected as a control since it had little cultivation and only 50 head of cattle.

MODELS

Two watershed-scale water quality models, AGNPS (Agricultural Non-Point Source Pollution) and SWRRB-WQ (Simulator for Water Resources in Rural Basins - Water Quality) were tested against the Pine Lake data.

AGNPS (Young *et al.*, 1987) is a summer storm event model. It simulates runoff, erosion, sediment and nutrient transport and feedlots on a cell basis. The watershed is divided into uniformly square cells. A feedlot evaluation model developed by Young *et al.* (1982) calculates manure point sources. An annualized, continuous simulation version of AGNPS is in development.

SWRRB-WQ (Arnold *et al.*, 1990) is an annualized, continuous simulation model. SWRRB-WQ does simultaneous sub-basin computations for weather, surface runoff,

groundwater flow, pond/reservoir storage, evapotranspiration, percolation and snowmelt. From the non-point source pollution perspective, SWRRB-WQ simulates sediments (yield and routing), pesticides and nutrients. It does not have a component for calculating manure point sources. The PC version of SWRRB-WQ is limited to modelling ten sub-basins. A more powerful model, SWAT (Soil Water Assessment Tool) runs on UNIX with GRASS, a public domain GIS, and can handle hundreds of sub-basins (Srinivasan *et al.*, 1993).

METHODOLOGY

The models required input files containing attributes such as land uses, soil properties, hydrologic conditions and point sources (feedlots and barnyards) in each sub-basin. Databases were created for the sub-basins from an amalgamation of information obtained from the manuals of the models, literature, provincial soils databases, Pine Lake limnological studies (Mitchell and Prepas, 1990; Sosiak and Trew, 1994) and field data. The analyses performed for this project consisted of: (1) examination of watershed weather data; (2) estimation of effective drainage areas; (3) characterization and classification of sloughs and other wetlands; and (4) application and evaluation of the water quality models.

Model Evaluations

The results from the models were compared with the data collected by Sosiak and Trew (1994) during the Pine Lake diagnostic study of 1992. The comparisons of predicted and observed data consisted of both qualitative and quantitative evaluations.

Qualitative Evaluations: The qualitative evaluations of the models incorporated both graphical and subjective comparisons of model predictions versus observed data. In the case of AGNPS, the qualitative comparisons examined the utility of the model in identifying critical areas, and whether they matched the critical areas identified by Sosiak and Trew (1994). The qualitative evaluations of SWRRB-WQ assessed how well the model simulated the hydrology of the sub-basins due to its lack of feedlot/livestock loading components.

Quantitative Evaluations: The quantitative evaluations of the models involved the computation of the average error (AE), relative error (RE), standard error (SE) and coefficient of variation (CV) of the results. These parameters were obtained from the following equations (Clemente *et al.*, 1994):

$$AE = \frac{1}{n}\sum_{i}^{n}(P_i - O_i) \qquad (2)$$

$$RE = AE \Big/ \bar{O} \qquad (3)$$

$$SE = \left[\frac{1}{n}\sum_{i}^{n}(P_i - O_i)^2\right]^{0.5} \qquad (4)$$

$$CV = SE \Big/ \bar{O} \qquad (5)$$

where P_i is a predicted value, O_i is an observed quantity, $\bar{O}$ is the mean of observed data,

and n (i=1,...,n) is the number of data pairs. AE is a parameter which quantifies prediction errors in measurement units (e.g., kg, mg/L or m^3/s). RE is a numerical representation of percentage over or under-prediction. SE and CV are numerical indicators of the variability in predicted data.

RESULTS AND DISCUSSIONS

AGNPS

The results from the qualitative evaluations of the output from AGNPS indicated good agreement, in terms of phosphorus (P) generation, between the critical areas reported by Sosiak and Trew (1994) and those predicted by the model. AGNPS also reported that dissolved P concentrations increased by 200-300% for a 1-year storm and about 800% for a 10-year storm due to livestock loadings. This confirmed that feedlots or wintering sites close to watercourses have a definite impact on the water quality of creeks draining into Pine Lake.

The outcome from the quantitative evaluations of AGNPS are summarized in Table 2. These results show that the model's predictions in terms of total phosphorus loadings did not agree with the observed data. In terms of discharges, AGNPS predicted no flow if a storm had a precipitation depth less than 25 mm (1"), and in Pine Lake storms exceeding this depth were rare.

While the errors (Table 2) are significant, AGNPS predictions of total phosphorus were reasonable if assumed antecedent moisture conditions are either dry or average. For a semi-humid climate, the model would rarely simulate wet antecedent moisture conditions. Also, AGNPS had to mimic small storms, small runoffs and low phosphorus loads. Since AGNPS is designed to model erosion events not low flow events, the numerical accuracy achieved is acceptable.

Table 2 Results from the quantitative evaluations of AGNPS output.

	No. Events	Total Phosphorus (Daily Mean)		AE (kg)	RE (%)	SE (kg)	CV
		Observed (kg)	Predicted (kg)				
Sub-basin 3							
Dry *			0.00	-0.54	-100	1.40	2.60
Average	102	0.54	1.41	+0.87	+162	10.09	18.77
Wet			14.55	+14.01	+2607	78.28	145.61
Sub-basin 4							
Dry			0.00	-0.59	-100	1.09	1.84
Average	127	0.59	1.10	+0.50	+85	11.39	19.13
Wet			16.37	+15.77	+2655	97.69	164.47
Sub-basin 7							
Dry			0.00	-0.20	-100	0.29	1.42
Average	26	0.20	0.00	-0.20	-100	0.29	1.42
Wet			0.00	-0.20	-100	0.29	1.42

* Dry, average and wet refer to the antecedent moisture conditions for SCS curve numbers.

SWRRB-WQ

The cumulative discharges predicted by SWRRB-WQ were very close to the observed cumulative discharges (Table 3) although there were considerable differences on event by event basis, especially during the spring snowmelt season. Also, the model under-predicted evapotranspiration (ET) when compared to ET estimated from pan evaporation data due to the lack of measured saturated hydraulic conductivities and on-site solar radiation data.

Table 3 Results from the quantitative evaluations of SWRRB-WQ output.

	Cumulative Discharges*		AE (m^3)	RE (%)	SE (m^3)	CV
	Observed (m^3)	Predicted (m^3)				
Sub-basin 3	243993.60	237753.60	-20.53	-2.13	5103.19	5.2916
Sub-basin 4	392169.60	388810.80	-11.05	-0.70	7568.09	4.7859
Sub-basin 7	232675.20	213764.80	-62.21	-6.60	3881.46	4.1204

* Period between February 29 and November 30, 1992.

According to the output of SWRRB-WQ, the rankings of dissolved (soluble) phosphorus generated by the three sub-basins were similar to that observed by Sosiak and Trew (1994). Of the three compared sub-basins, Sub-basin 4 was ranked as first, Sub-basin 3 as second and Sub-basin 7 as third. Since SWRRB-WQ does not simulate livestock loadings, the predicted rankings could be merely a reflection of relative sizes of the cropped and effective drainage areas of the three sub-basins.

CONCLUSIONS

The evaluations of AGNPS and SWRRB-WQ have shown the utility of simulations from water quality models in pin-pointing critical areas due to livestock loadings and predicting hydrologic events. Although there were discrepancies between observed and predicted values, both models have fared well considering the nature of the Pine Lake watershed in terms of topography and land use. Nevertheless, this study has shown that the impact of animals on phosphorus loads is significant as predicted by AGNPS although it is a complex function of number of animals, land slope, SCS curve number, soil type, land use upslope and downslope of feedlots/barnyards, and distance to watercourses. In addition, the project revealed deficiencies in our databases, specially our lack of reliable data on soils, antecedent moisture conditions, evaporation/evapotranspiration and solar radiation.

Until the annualized version of AGNPS with components that represent the effects of spring snowmelt conditions is released, the use of AGNPS for this project will be limited to summer storms which are not productive in terms of runoff and phosphorus loads unless storms have return periods greater than 1 year. Also, the results have confirmed that AGNPS is to be used as a management tool rather than as a predictive tool. In the case of SWRRB-WQ, water quality simulations will be restricted to those stemming from cropped lands until a version of SWRRB-WQ that incorporates the effects of feedlots or barnyards is developed. Finally, we also found that observations along the main creeks or watercourses, particularly during spring snowmelt, are necessary for proper validation of water quality models, or for possible implementation of water quality mitigation plans in Alberta.

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PRELIMINARY ASSESSMENT OF THE IMPACT OF RUNOFF FROM BEEF FEEDLOT PENS

B. Kennedy, R. Coleman, W. Sawchuk, N. MacAlpine,
G. Gillund[1]

Introduction

Finishing beef in feedlots is an expanding industry in Alberta. Alberta feedlots finish 65 percent of Canada's beef. As the feedlot industry expands, it is taking advantage of the readily available feed and other required operating resources in the central portion of the province.

Alberta feedlots range in size from a few head to tens of thousands. Most feedlots have bare earth pen surfaces, feedbunks and windbreak fences. A feedlot's area may range in size from a few hundred square feet to several hundred acres. Most of the planning for feedlots are based upon the feeding operation and the cattle handling facilities. Controls for waste management may vary from non-existent to some very sophisticated designs, with drainage and collection ponds.

Society, and in particular rural neighbours are becoming more concerned about the environmental impact of the cattle feeding industry. Odours, runoff and manure use are the principle concerns. Feedlot runoff contains nutrients, bacteria, microfauna/flora, faecal material, sediments and has a high chemical oxygen demand (COD).

Presently there is limited data, under Alberta conditions, about quantity and quality of feedlot runoff. This data is necessary to plan environmentally sound feedlot runoff control and re-use onto agricultural land. As a result this project was initiated with two main objectives.:

1. To measure rainfall and snowmelt runoff from the feedlot pen area.
2. To collect data on feedlot runoff microbiological and chemical parameters.

Instrumentation

ISCO model 3700 automatic samplers were used to collect water at all sample sites.

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Temperature, relative humidity and rainfall are collected electronically, using a Campbell Scientific CR10 datalogger, a Model 207C temperature and humidity probe and a tipping bucket rain gauge. A Class A evaporation pan provides evaporation data. V-notch weirs in culverts and Stevens water level recorders measure runoff. The V-notch weirs were calibrated by conducting an artificial runoff event. The culverts with the V-notch weirs were covered with a piece of plywood. Water was pumped into the area behind each culvert and once the plywood dam was removed, the velocity and flow depth in the culvert was measured versus the depth of head at the V-notch weir. This data was then used to produce rating curves of volumetric flow versus head for each of the V-notch weirs.

During the runoff season (April through October), the site and instruments are monitored on a weekly basis. Samples are collected from the runoff collection ponds and analyzed for microbiology and chemistry parameters. At each runoff event, automatic samplers sample the runoff from Sites 2 and 3. These samples are immediately collected and analyzed for microbiology and chemistry parameters. During runoff events water levels at the V-notch weirs are measured by the Stevens level recorders. Periodically free surface levels in the holding ponds are recorded.

Microbiological Methods

All samples were collected, transported and stored as outlined in the Alberta Environmental Centre Microbiological Methods Manual (Coleman, 1990).

Chemical Methods

All samples were collected, transported and stored as outlined in the Alberta Environmental Centre Methods Manual for Water and Wastewater (Dieken,1987).

Results

Highland Feeders Ltd. has a modern 18,000 head feedlot north of Vegreville, Alberta. The feedlot was constructed in three separate but similar designed sections. Each section is built with two rows of pens back to back. The area between the pens is used both as cattle sorting alleys and drains. Feedbunks and roadways are built along the outside of the pens. From the feedbunks the pens slope toward the drain, which in turn, moves the runoff to holding ponds.

The first phase of construction took place in 1988. This area is know as Site One for the study. There is a total of 5000 head of cattle housed in this portion of the feedlot. The total area is 8.047 hectares, with a pen slope of 2.5%. The liquid effluent drains to the holding pond.

The second phase of construction took place in September of 1992. Known as Site Two for the study, this area houses up to 7000 head. The total area is 16.125 hectares, with a pen slope of 2.5%. The liquid effluent drain through culverts and under the roadway to

the large collection pond in the southeast portion of the feedlot.

The third phase of construction took place in 1993. This is known as Site Three for the study. A total of 6000 head are housed in this portion. Site Three has an area of 10.612 hectares and the pen slope is also 2.5%. The liquid effluent drain through culverts, under the roadway, to the large collection pond in the southeast portion of the feedlot.

Phase four of the feedlot is to be built during the spring and summer of 1995. The site will be monitored and instruments installed as it comes on line.

All pen section run north-south, on a south facing slope, taking advantage of the natural slope of the land. Landscaping is used not only to divert runoff from above the feedlot around the pens, but to construct drains and holding ponds as well. The natural slope comes from a change in elevation of thirty meters from the northeast corner of the parcel to the southeast corner of the parcel.

Soils at the feedlot site are a clay-loam on a clay subsoil containing a few sand lenses.

Operation of the feedlot involves feeding the cattle, providing bedding for their comfort and removal of manure. During winter, chopped straw is added to a manure pack to provide a bedded area for the cattle. In early spring, on the frost, the manure pack is mounded. The pens are scrapped and a mixture of manure and snow is removed. This system of manure management results in rapidly drying pen surfaces and a minimum of snowmelt runoff. During the summer months pens are scraped regularly and the materials added to the manure mounds. After silage has been harvested from the adjoining fields, manure from the pens is hauled and spread on the silage stubble.

During the 1994 season, the collection pond filled up. This required draining the pond and irrigating 10 cm of effluent on 16 ha of land during mid-October, 1994.

Little snow runoff was evident from the feedlot pens during the spring of 1994. The estimated volume of snowmelt for Site 2 was 454,000 litres. Volumes were estimated, not measured, because of snow removal during spring cleaning of the pens. Snow depths around the feedlot were: 7.9 cm water equivalent on the north side, 9.1 cm on the east side and 6.8 cm on the west side. During spring runoff, water level recorders were not used because of problems with their operation caused by the diurnal freeze-thaw cycle.

With the exception of pH, most chemical parameters were present at extremely high values. Calcium, sodium, potassium, and chloride varied from low values (21 ppm, 43 ppm, 65.1 ppm & 68.3 ppm respectively) to high values in early September (162 ppm, 647 ppm, 964 ppm, & 1235 ppm respectively). Chemical Oxygen Demand (COD) values were lowest in March (423 ppm) but highest in early July (14,689 ppm). Total N was also lowest in March (41.1 ppm) and highest in early July (500 ppm) and early August (518 ppm).

NH_3-N followed a similar trend to TKN but with some inconsistency. Total P tended to be lowest in spring (8.23 ppm) and spiked at 103 ppm in June.

Conclusions

Although these data are preliminary, they do suggest that runoff control and short term containment must be carefully planned. At the same time effective and environmentally acceptable use of the contained runoff must be considered. This project is now entering its second year with the potential to improve data collection and our understanding of feedlot dynamics.

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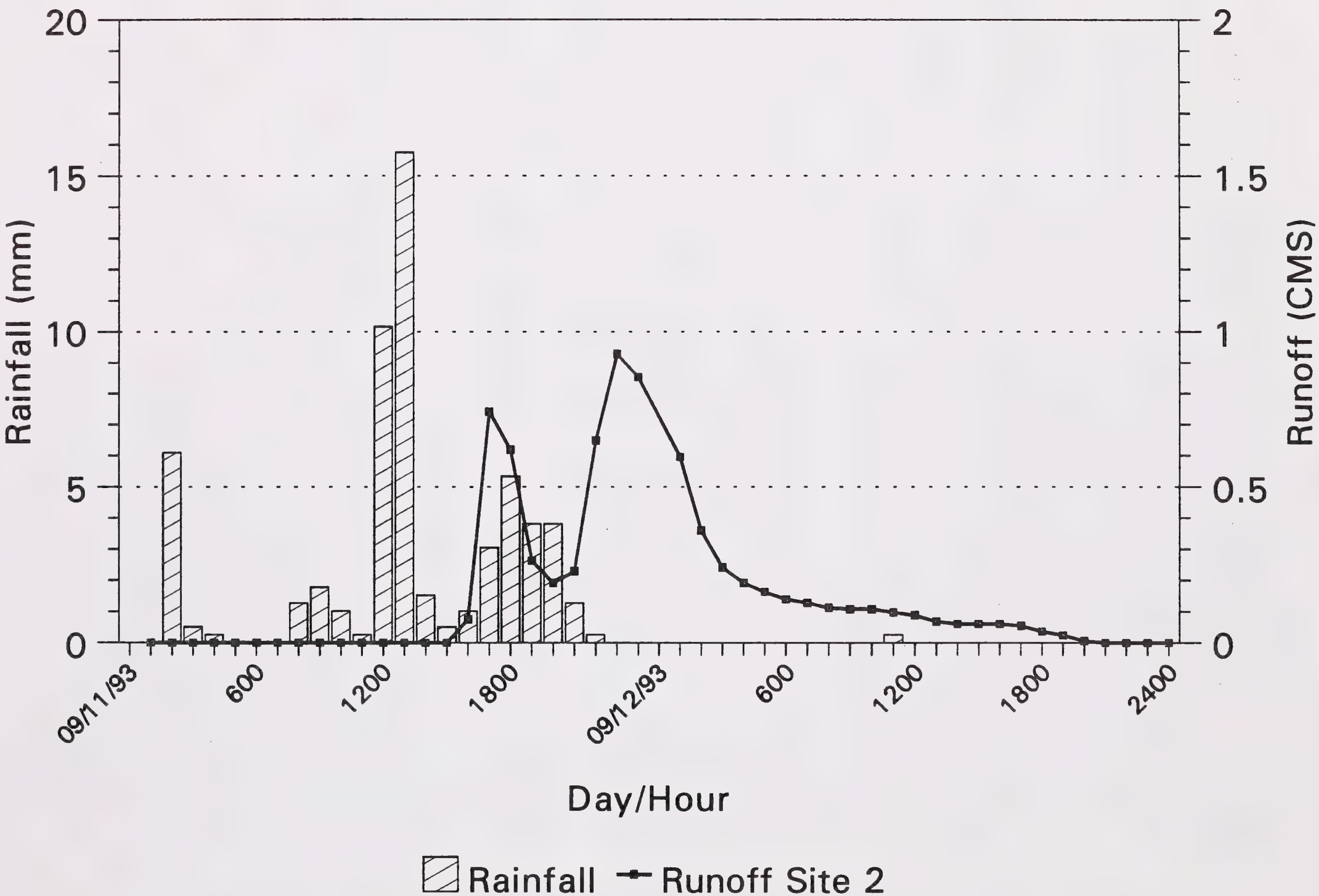
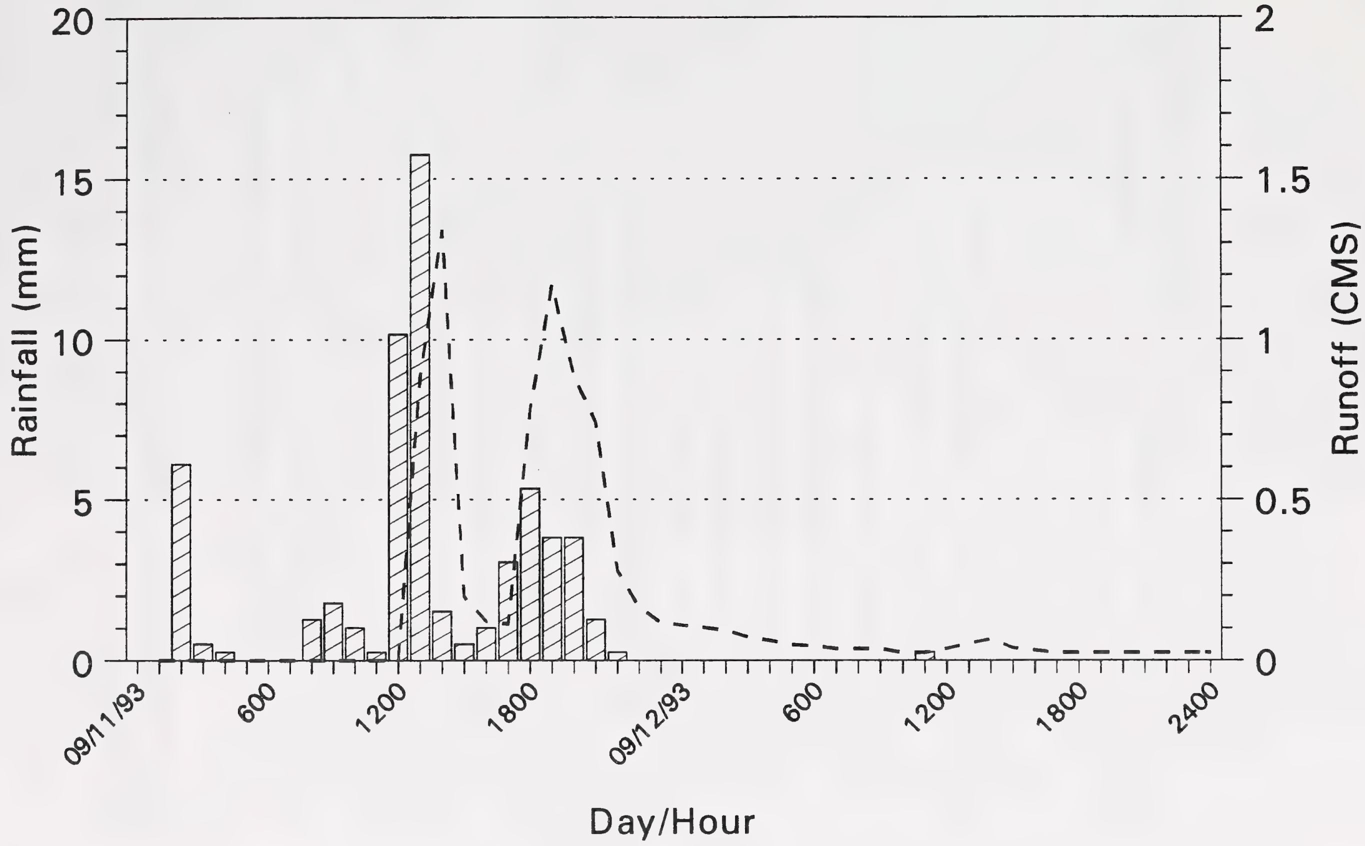
Figure 1.
Rainfall and Associated Runoff for a Storm Event at Site 2 (1993)



Pen Area = 16.2 ha. (Constructed Sept. 1992)

Figure 2.
Rainfall and Associated Runoff for a Storm Event at Site 3 (1993)



Pen Area = 10.6 ha. (Constructed Sept. 1993)

Figure 3.

Results of Selected Chemical Parameters

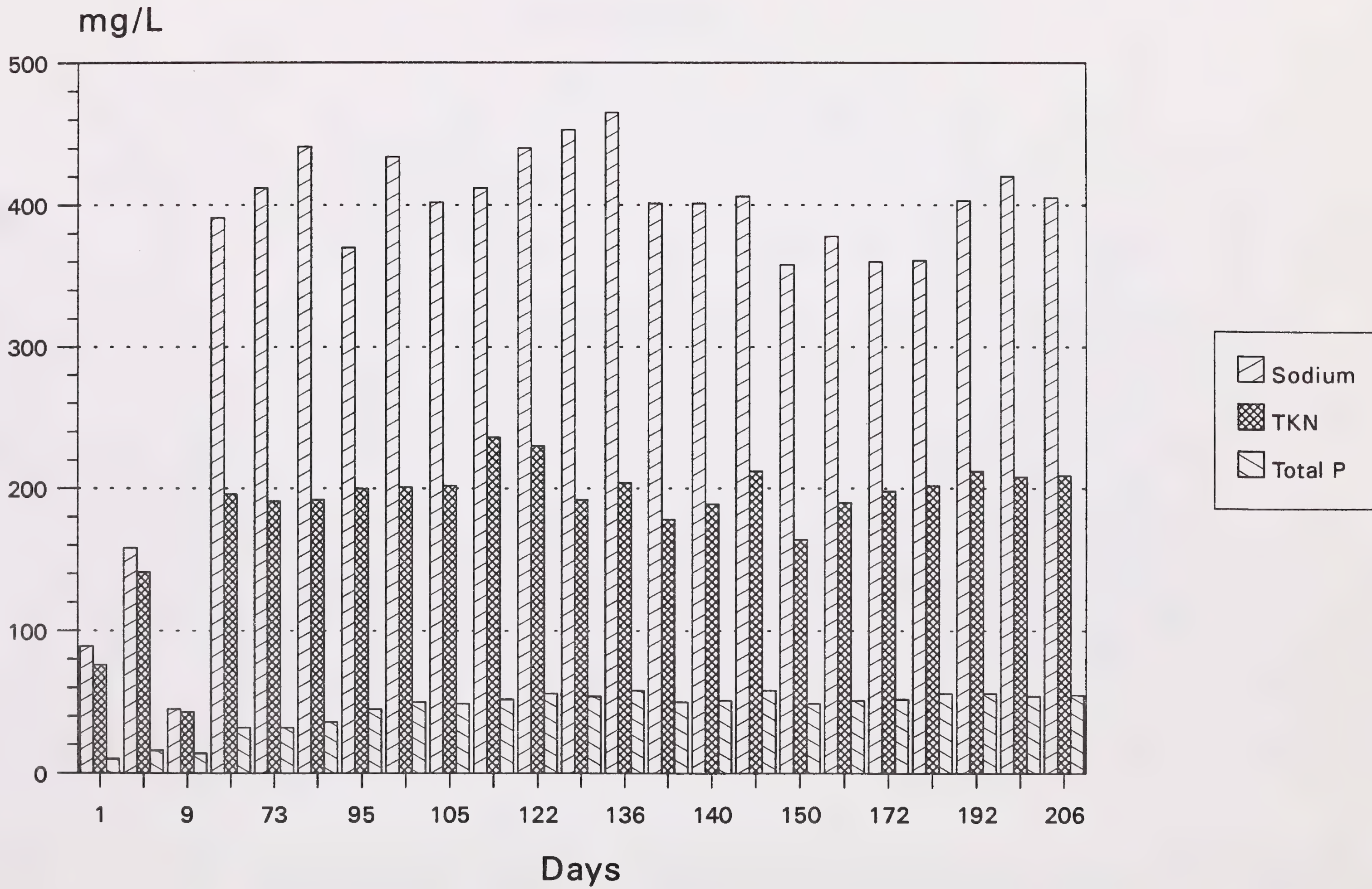
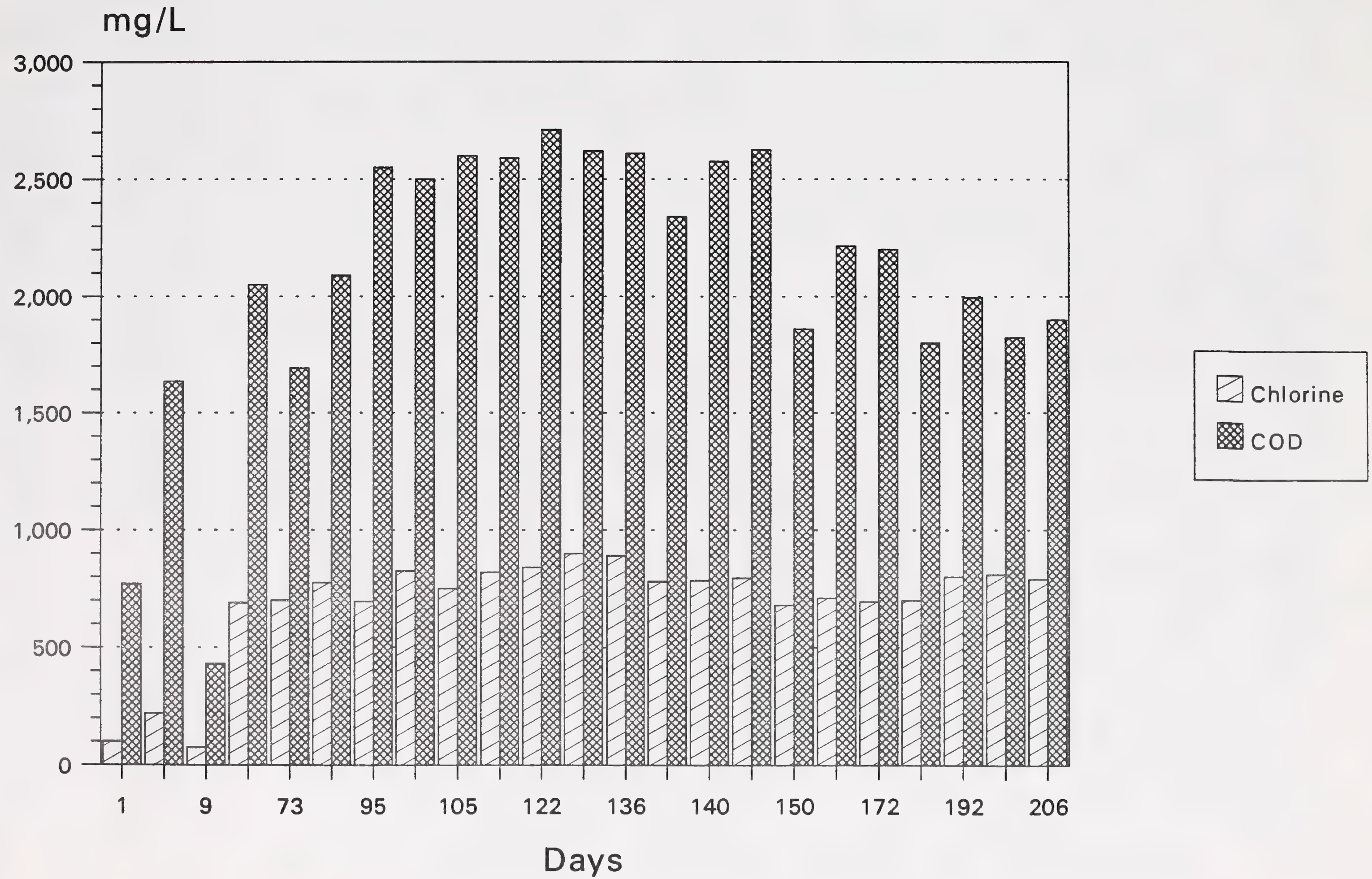


Figure 4.

Results of Selected Chemical Parameters



IMPACT OF CURRENT MANURE MANAGEMENT PRACTICES ON SURFACE WATER QUALITY IN THE COUNTY OF LETHBRIDGE (YEAR ONE - 1994)

G. M. Greenlee, P.Ag. and P. D. Lund[1]

INTRODUCTION

Nitrate and coliform bacteria contamination of surface waters in Alberta has been attributed to a number of agricultural practices, including improper handling and disposal of manure (Bow River Water Quality Task Force 1991). Improper manure management practices, such as high disposal rates, increase the risk of surface water contamination (Sutton and Joern 1992). The two compounds of most concern from a water quality perspective are nitrogen and phosphorus (Ritter 1988).

The quality of water used in the irrigation districts of southern Alberta is considered excellent, with average salinity levels from 0.28 to 0.38 dS m^{-1}, average sodicity levels from 0.3 0.6 and average total dissolved solids from 154 to 212 mg L^{-1} (Hamilton et al. 1982). Irrigation water is derived primarily from southern Alberta's major rivers which originate as snow-melt in the Rocky Mountains.

The portion of the Lethbridge Northern Irrigation District (LNID) that is situated in the County of Lethbridge has one of the highest feedlot densities in Alberta, with more than 60 percent of the operations north of the Oldman River. The objective of this study was to assess the quality of water entering and leaving a drainage sub-basin (Battersea Drainage Basin), in order to evaluate the impacts of the intensive livestock feeding industry on the quality of surface waters.

Nonpoint source pollution from animal agriculture may result from livestock production on pastureland, animal confinement facilities (feedlots) and manure disposal areas (Ritter 1988). Animal manure may include animal excrement (including urine), wastewater, spilled feed, open feedlot runoff and bedding (Sutton and Joern 1992). The potential pollutants in manure are organic matter, plant nutrients (nitrogen, phosphorus), infectious diseases (microorganisms) and inorganic salts (Brichford et al. 1993). Animal wastes have high salt content which results from feed rations. When high rates of manure are applied to land, excessive salts may accumulate in the soil profile. Grazing animals deposit manure directly on the land in pastures, and manure may become concentrated near feeding and watering areas (Sutton 1990). Livestock allowed to stand in streams or ponds deposit manure directly into surface waters.

METHODS

The Battersea Drainage Basin is located in the LNID portion of the County of Lethbridge (Fig. 1). Surface water quality monitoring sites included the outlet of Picture Butte Reservoir, the Haney Drain return flow stream and the Battersea Drain

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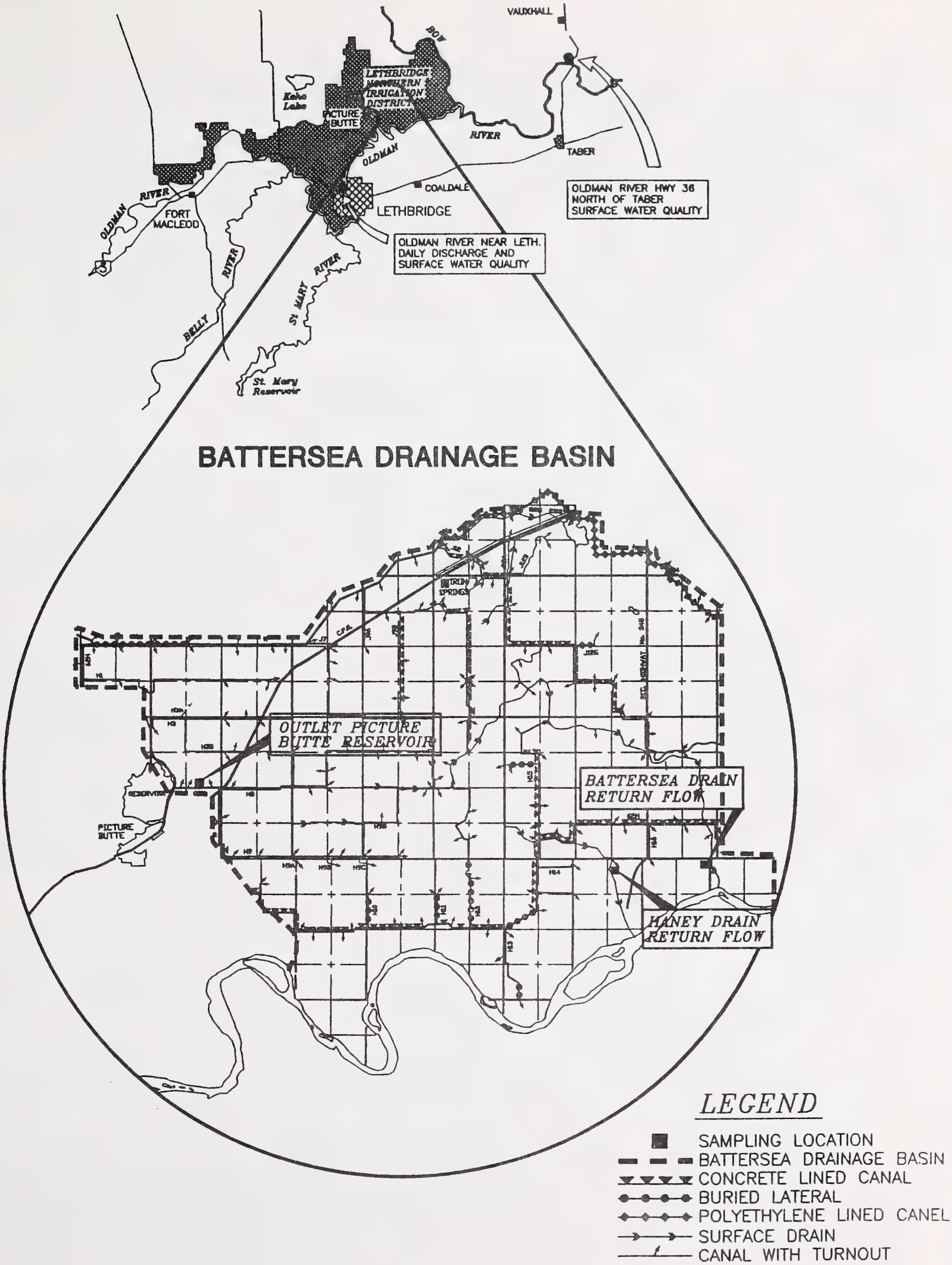

Figure 1. Surface water quality monitoring sites and mean daily water discharge monitoring site.

return flow stream. Surface water grab samples were collected weekly from May 11 through October 11. Data from two Oldman River monitoring sites was obtained from Alberta Environmental Protection.

Water samples were filtered and analyzed for pH, electrical conductivity (EC), soluble cations (calcium, magnesium, sodium, potassium), soluble anions (sulfate, chloride, carbonate, bicarbonate, nitrate, phosphate), total and faecal coliforms using standard analytical techniques (Greenberg et al. 1992). Nitrate was determined using the Technicon Traacs 800 Industrial Method No. 782-86T. Sodium adsorption ratio (SAR) and total dissolved solids (TDS) were calculated. Water samples were also analyzed for five trace elements (arsenic, cadmium, copper, lead, selenium) using atomic absorption spectrometry.

RESULTS AND DISCUSSION

LNID Sites

Salinity, Sodicity and TDS: Average salinity, sodicity and TDS levels increased slightly in the Battersea Drain return flow stream and increased markedly in the Haney Drain return flow stream (Table 1, Fig. 2). Constituent values fluctuated widely in the Haney Drain return flow stream during the monitoring period. Salinity levels were well above the Canadian water quality guideline lower limit for irrigation on several occasions and were above the upper limit for irrigation on two occasions (Table 2). TDS concentrations were well above the guideline for human consumption on several occasions. The TDS value was above the guideline for human consumption in the Battersea Drain return flow stream on the first sampling day of the season. All other constituent levels were below the guidelines for human/livestock consumption and irrigation throughout the monitoring period.

Nitrate: Nitrate was detected occasionally in the Picture Butte Reservoir outlet and in the Battersea Drain return flow stream. A concentration of 7 mg L^{-1} occurred on the first sampling day of the season in the Battersea Drain return flow stream (Fig. 2). All other values at these two sites were well below 1 mg L^{-1} (Table 1). Nitrate was found on most sampling dates in the Haney Drain return flow stream, and values were often well above the limit for human consumption (Table 2). A nitrate level of 110 mg L^{-1}, above the limit for livestock consumption, occurred on July 20 at this site.

Phosphate: Phosphate was not detected in the Picture Butte Reservoir outlet, and a concentration of 0.02 mg L^{-1} was observed only once (May 24) in the Battersea Drain return flow stream (Table 1). Phosphate was found infrequently in the Haney Drain return flow stream, and values were usually above the maximum desirable concentration of 0.10 mg L^{-1} for flowing water (EPA 1976). The highest concentration observed was 0.63 mg L^{-1} on June 8.

Total and Faecal Coliforms: Total and faecal coliform numbers fluctuated widely during the monitoring period (Table 1, Fig. 2). Levels were consistently well above the limits for human/livestock consumption and often above the limit for irrigation (Table 2). Average values were higher in the Battersea Drain return flow stream than in the Picture Butte Reservoir outlet, and the highest levels occurred in the Haney Drain return flow stream.

Trace Elements: Trace element levels were below detection limits during most

of the monitoring period, with the exception of copper (Table 3). The cadmium concentration was below the detection limit at all sites throughout the monitoring period. Trace elements detected were at very low concentrations, and copper was found on most sampling dates at all sites. Lead was detected only once in the Picture Butte Reservoir outlet and in the Haney Drain return flow stream, and was not detected in the Battersea Drain return flow stream. All trace element values were below the guidelines for human/livestock consumption and irrigation (Table 2).

Table 1. Salinity, sodicity, total dissolved solids, nitrate, phosphate, total and faecal coliform levels[1].

Monitoring Site	EC^2	SAR^2	TDS^2	NO_3-N^2	PO_4-P^2	Total Coliforms	Faecal Coliforms
	ds m^{-1}		mg L^{-1}			count 100 ml^{-1}	
Picture Butte Reservoir Outlet	0.32 (0.02)	0.66 (0.17)	182 (18)	0.006 (0.03)	0	292 (297)	136 (177)
Haney Drain Return Flow	1.54 (1.14)	1.37 (0.71)	1955 (2033)	13.32 (25.16)	0.07 (0.16)	15,343 (38,133)	7497 (17,881)
Battersea Drain Return Flow	0.39 (0.05)	0.68 (0.16)	241 (36)	0.32 (0.05)	0.001 (0.004)	605 (589)	250 (272)
Oldman River near Lethbridge[3]	0.36 (0.02)	0.45 (0.10)	203 (13)	0.01 (0.03)	0.004 (0.008)	1450[4] (550)	143 (115)
Oldman River Hwy 36 north of Taber[3]	0.36 (0.03)	0.58 (0.13)	207 (20)	0.02 (0.04)	0.008 (0.009)	555[4] (45)	124 (118)

[1] Mean values, with standard deviation in parenthesis.
[2] EC = electrical conductivity, SAR = sodium adsorption ratio, TDS = total dissolved solids, NO_3 -N = nitrate nitrogen, PO_4-P = phosphate phosphorus.
[3] Data from Environmental Assessment Division, Surface Water Monitoring Branch, Alberta Environmental Protection, Edmonton, Alberta.
[4] Data for May and June only.

Table 2. Canadian water quality guidelines.[1]

Parameter	Human Consumption	Livestock Consumption	Irrigation
EC (ds m^{-1})	na	5	<1 - 2.5
SAR	na	na	<4 - 9
mg L^{-1}			
TDS	500	3000	500 - 3500
NO_3	10	100	na
Arsenic	0.025	0.5	0.1
Cadmium	0.005	0.02	0.01
Copper	1.0	Cattle 1.0 Sheep 0.5 Swine & Poultry 5.0	0.2
Lead	0.01	0.1	0.2
Mercury	0.001	0.003	nrg[2]
Selenium	0.01	0.05	0.02
count 100 ml $^{-1}$			
Total Coliforms	10	10	1000
Faecal Coliforms	0	0	100

[1] CCREM 1987 and updates, Alberta Agriculture 1992, FPSDW 1993.
[2] na - not applicable, nrg - no recommended guideline.

Possible reasons for the high constituent levels in the Haney Drain return flow stream were:

1) a large beef feedlot situated adjacent to the drain about a mile upstream from the monitoring site,
2) surface runoff from agricultural land adjacent to the drain upstream from the monitoring site, or
3) the fact that cattle had free access to the drain in the vicinity of the monitoring site during the monitoring period.

A second monitoring site will be established in 1995, upstream from the 1994 site at a location where cattle don't have access. Data collected from the new site should indicate the proportion of constituents resulting from the presence of cattle at the old site.

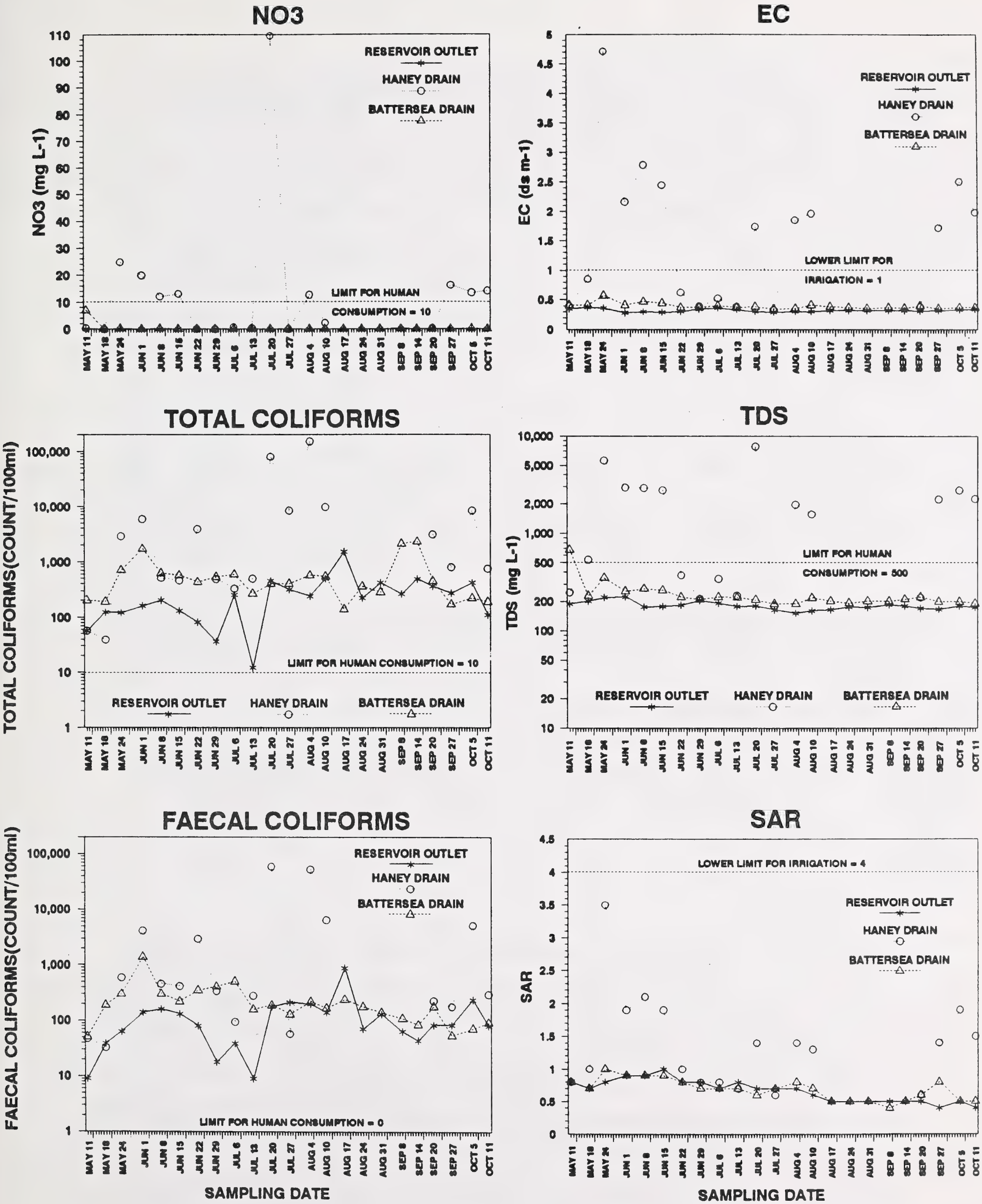

Figure 2. Seasonal salinity, sodicity, total dissolved solids, nitrate, total and faecal coliform levels from LNID sites.

Table 3. Trace element concentrations.

Monitoring Site	As	Cd	Cu	Pb	Se
	mg L^{-1}				
Picture Butte Reservoir Outlet[1]	<0.001 to 0.002	<0.001	<0.001 to 0.006	<0.001 to 0.006	<0.001 to 0.002
Haney Drain Return Flow[1]	<0.001 to 0.007	<0.001	<0.001 to 0.010	<0.001 to 0.001	<0.001 to 0.005
Battersea Drain Return Flow[1]	<0.001 to 0.002	<0.001	<0.001 to 0.030	<0.001	<0.001 to 0.002
Oldman River near Lethbridge[2]	0.0003[3] to 0.0013	<0.0002[3,4]	<0.001[1,4] to 0.002	<0.001[1,4] to 0.001	<0.0002[3] to 0.0003
Oldman River Hwy 36 north of Taber[2]	0.0003[3] to 0.0009	<0.0002[3,4]	<0.001[1,4] to 0.003	<0.001[1,4]	<0.0002[3] to 0.0003

[1] Detection limit 0.001 mg L^{-1}
[2] Data from Environmental Assessment Division, Surface Water Monitoring Branch, Alberta Environmental Protection, Edmonton, Alberta, monthly readings May through October.
[3] Detection limit 0.0002 mg L^{-1}
[4] Data for July and October only.

Oldman River Monitoring Sites

Salinity, Sodicity and TDS: Average salinity and TDS levels did not increase between the Lethbridge site and the highway 36 site, were higher than in the Picture Butte Reservoir outlet and were lower than in the Battersea Drain return flow stream (Table 1). Average sodicity values increased between the Lethbridge site and the highway 36 site, and were lower than at the LNID sites. The highest constituent concentrations occurred in the Haney Drain return flow stream.

Nitrate: Average nitrate levels were very low and were much lower than at the LNID sites (Table 1). The highest concentration of 0.12 mg L^{-1} occurred at the highway 36 site on May 18.

Phosphate: Very low levels of phosphate were found infrequently, and values were much lower than in the Haney Drain return flow stream (Table 1).

Total and Faecal Coliforms: Coliform numbers were consistently above the limits for human/livestock consumption (Table 1, Table 2). The total coliform level at the Lethbridge site was above the limit for irrigation on June 14, and faecal coliform values were often above the limit for irrigation at the highway 36 site. Numbers were similar to those in the Picture Butte reservoir outlet and in the Battersea Drain return flow stream. Coliform levels were much lower than in the Haney Drain return flow stream.

Trace Elements: Cadmium was not detected during the monitoring period, and lead was not detected at the highway 36 site (Table 3). Very low levels of all other trace elements were found on most sampling dates at both sites. Trace element concentrations were generally lower than at the LNID sites.

Impact of Irrigation Return Flow

The impact of irrigation return flow water on receiving rivers is diminished by the dilution effect. This ranged from 47 to 316 times for the Battersea Drain return flow stream, and from 778 to 31,500 times for the Haney Drain return flow stream (Table 4). Other processes that reduce constituent concentrations in receiving streams and major water bodies to lower levels than those in edge-of-field runoff include sedimentation, vegetative trapping and degradation in transport (Leonard 1990).

Table 4. Mean daily water discharge ($m^3 S^{-1}$) in return flow streams and Oldman River during 1994.

Month	Oldman River Near Lethbridge[1]	Battersea Drain Return Flow[1]	Dilution Factor	Haney Drain Return Flow[2]	Dilution Factor
May	189	0.599	316	0.006	31,500
June	121	0.515	235	0.019	6,368
July	28.8	0.611	47	0.037	778
August	30.4	0.508	60	0.001	30,400
September	26.5	0.551	48	0.016	1,656
October	32.0	0.378	85	--	--

1 Preliminary data from Environment Canada, Environmental Monitoring and Systems Branch, Monitoring Operations Division, Water Survey of Canada, Calgary, Alberta

2 Data from Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta.

PRELIMINARY CONCLUSIONS

Preliminary data from a small irrigation return flow stream (the Haney Drain) suggested a significant impact of current manure management practices on surface water quality. Data from a large irrigation return flow stream (the Battersea drain) suggested a minor impact. High constituent levels in the Haney Drain return flow stream were likely due to the near proximity of a large feedlot, to the free access of cattle to the monitoring site, or to a combination of both factors. Another factor could be the low flow volumes in the Haney Drain return flow stream, which would result in more concentrated levels of constituents than in the Battersea Drain return flow stream, which had much higher flow volumes (data not shown). Further monitoring will be required to try and identify factors causing high constituent concentrations.

Coliform bacteria counts consistently exceeded the Canadian drinking water guidelines at all monitoring sites. Raw water from irrigation canals and return flow streams should receive adequate filtration and disinfection treatment to make it safe for human consumption.

A very small impact of irrigation return flow streams on surface water quality in a major receiving stream (the Oldman River) was attributed to substantial dilution of the return flow streams when they enter the river.

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Agriculture and Agri-Food Canada Research Branch,
Lethbridge Northern Irrigation District,
Alberta Environmental Protection,
Alberta Cattle Feeders Association,
Alberta Water Resources Commission.

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LAND AVAILABILITY FOR MANURE DISPOSAL IN THE LNID PORTION OF THE COUNTY OF LETHBRIDGE, ALBERTA

D. Rodney Bennett and Echo McCarley[1]

INTRODUCTION

Contamination of surface waters and groundwater in Alberta has been attributed to a number of farming practices, including improper handling and disposal of manure (Bow River Water Quality Task Force 1991). Nitrate contamination of groundwater and accumulation of excess nitrate in soils has been observed in southern Alberta following annual applications of beef cattle manure at high rates (Chang et al. 1991; Riddell and Rodvang 1992).

The County of Lethbridge has the highest density of intensive livestock feeding operations (ILO's) in Alberta (Snowy Owl Software 1993). Manure disposal from large, confined, livestock and poultry feeding operations has become a growing concern, particularly in the LNID portion of the county. A particularly high density of sizeable operations exists in this area and some ILO's are constrained by the amount of owned, cultivated land available for manure disposal.

A study was initiated in 1992 to determine the extent of cultivated land near feeding operations that is available for manure disposal and to assess the potential for further expansion of the livestock feeding industry within the study area.

METHODS

Database requirements included: land ownership; location, type and capacity of each ILO; irrigated and dryland cultivated acreage; and, manure and nutrient production estimates. Land ownership for each parcel was taken from the 1994 map for the County of Lethbridge, and from the 1993 and 1994 LNID assessment rolls. The amount of cultivated land within each parcel was determined from 1990/91 colour (1:10,000) and 1993 black and white (1:30,000) aerial photos. Cultivated acreage was determined for both irrigated and dryland portions of each parcel based on the 1993 LNID assessment roll, with adjustments based on obvious changes in irrigation method (side wheel to pivot) and land use (Table 1).

The existing Oldman River Regional Planning Commission (ORRPC 1990) database was updated to locate each beef cattle, dairy, hog and poultry feeding operation in the study area. The number of animals (capacity) in each ILO was also estimated based on ORRPC data and field inspections in 1993 (Table 2). Annual manure production from each operation was calculated on the basis of animal numbers and typical manure production rates (Table 3)(ILO Code of Practice Subcommittee 1995).

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Table 1. Summary of cultivated land in the LNID portion of the County of Lethbridge

Total Area	70,800 ha
Cultivated/irrigated area	45,800 ha (65%)
Cultivated/dryland area	9,700 ha (13%)
Total cultivated area	55,500 ha (78%)
Cultivated area owned by ILO's	28,900 ha (41% of total; 52% of cultivated area)

Table 2. Capacity of each type of livestock feeding operation and conversion factors for manure and nutrient production (wet weight basis)

Type of ILO	Number of Animals	Manure Production (Mg/animal/yr)	Mineral Nitrogen (kg per Mg)	Phosphorus (P_2O_5) (kg per Mg)
Beef	323,260	2.4 (Solid)	2.75	5.5
Dairy	12,660	16.4 (Liquid)	1.85	2.0
Poultry	528,000	0.022 (Solid)	10.70	15.0
Hogs (f-f)	5005 sows	23.7 (Liquid)	1.65	2.5
Hogs (f-w)	2240 sows	7.3 (Liquid)	1.65	2.5
Hogs (feeder)	10,050	2.6 (Liquid)	1.65	2.5

Table 3. Total annual manure and nutrient production estimates (wet weight basis)

Type of ILO	Total Manure Production (Mg)	Total Mineral Nitrogen (Mg)	Total Phosphorus (P_2O_5) (Mg)
Beef	776,000	2,134,000	4,267,000
Dairy	208,000	384,000	415,000
Poultry	12,000	124,000	174,000
Hogs	161,000	266,000	403,000
TOTAL	1,157,000	2,908,000	5,259,000

Parcel identification numbers, land ownership, cultivated acreage, ILO types and animal numbers were entered onto computer using R:BASE, a relational database. A geographic information system (GIS) was subsequently developed for use in depicting the location of parcels containing irrigated and dryland cultivated acres, the location and attributes of each ILO, the location of all owned land associated with each ILO, and the relative rate of manure and nutrient application on owned land associated with each ILO.

RESULTS AND DISCUSSION

About two thirds of the ILO's in the LNID portion of the County of Lethbridge do not own sufficient land for long-term disposal of manure at a rate less than 20 Mg/ha (Table 4), a rate based on silage barley nitrogen requirements and manure management practices that minimize nutrient losses. About 80 percent of the ILO's own sufficient land for crop use of up to 180 kg/ha of mineral nitrogen released from an annual manure application (Table 5, Figure 1). However, repeated, annual applications of manure to the same land necessitate a gradual reduction in the rate due to mineralization of organic nitrogen from previous years (USEPA 1979). Thirty percent of the ILO's own sufficient land to use up to 60 kg/ha of phosphorus from the manure applied annually (Table 5).

Potential manure production from all ILO's in the study area (Table 3) would require 40,000 to 60,000 ha of cultivated land for repeated, annual application at about 20 to 30 Mg/ha, a rate based on crop nitrogen needs and sound manure management practices (Figure 2). Manure application rates based on crop phosphorus requirements would increase the amount of land required by at least 50 percent (Figure 1).

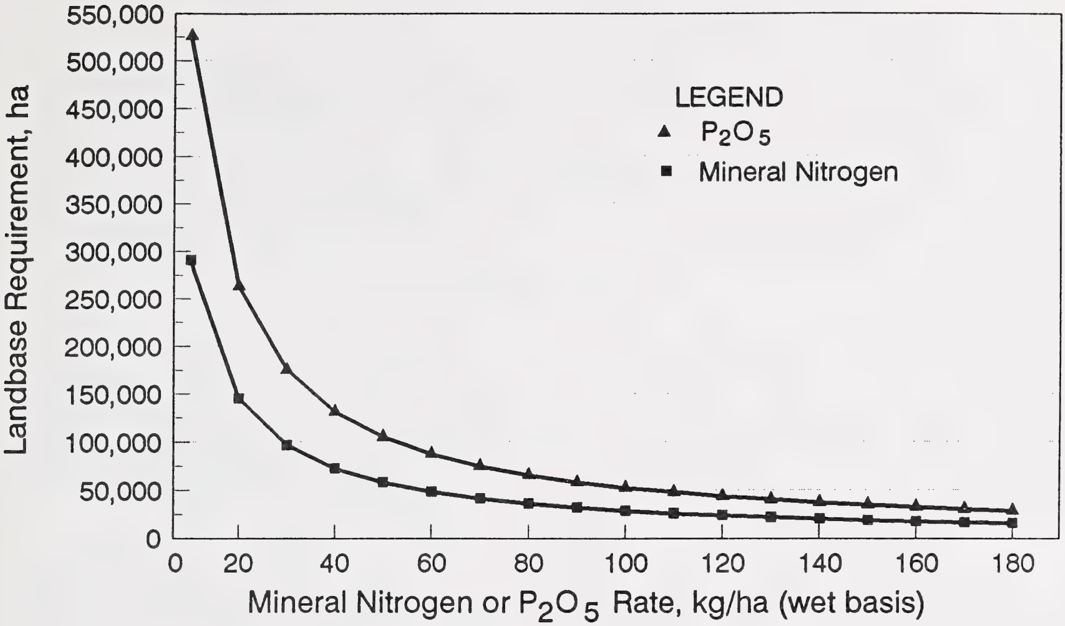

Figure 1. Landbase needed for different nutrient rates.

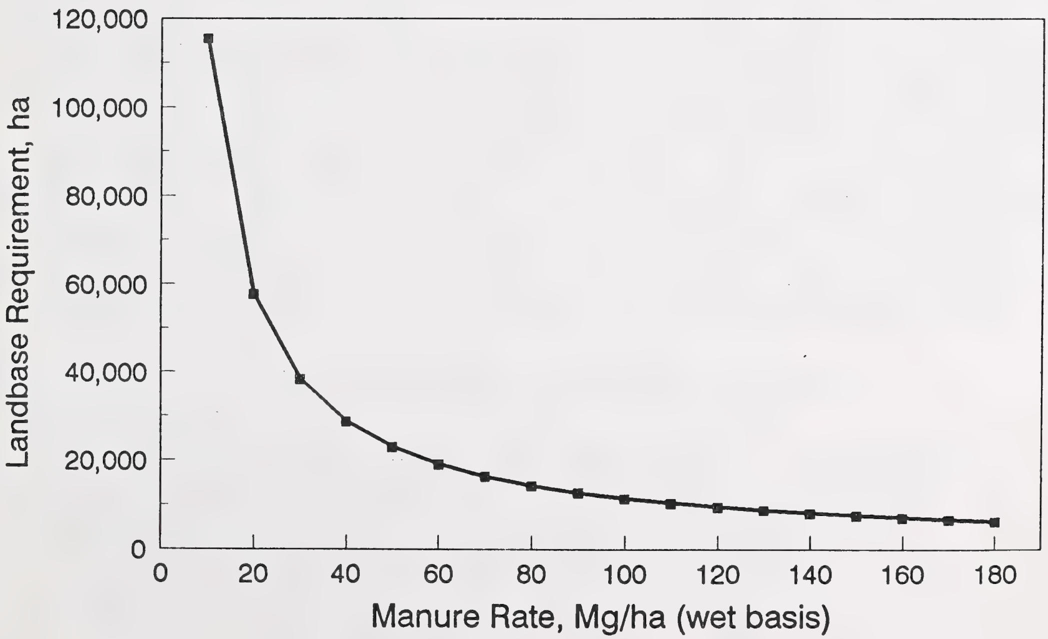

Figure 2. Landbase needed for different manure rates.

Table 4. Proportion of land owned by ILO's and number of operations in different manure rate categories

Manure Rate Mg/ha	Beef		Dairy		Poultry		Hogs		Total	
	Area (%)	ILO (%)	Area (%)	ILO (%)	Area (%)	ILO (%)	Area (%)	ILO (%)	Area (%)	ILO (%)
0 - 20	50	44	52	21	95	59	73	51	43	32
20 - 40	14	18	24	34	3	6	19	27	21	25
40 - 60	10	11	18	31	0	0	3	5	14	17
>60	26	27	6	14	2	35	5	17	22	26

NOTE: 34% of the total cultivated area associated with ILO's has more than one type of ILO.

Table 5. Proportion of land owned by ILO's and number of operations in different nutrient rate categories

Nutrient Rate kg/ha	Mineral Nitrogen		Phosphorus	
	Area (%)	ILO (%)	Area (%)	ILO (%)
0 - 60	53	44	35	29
60 - 120	21	25	26	25
120 - 180	8	11	8	12
>180	18	20	31	34

CONCLUSIONS AND RECOMMENDATIONS

One third of the ILO's in the LNID portion of the County of Lethbridge have sufficient land for repeated, annual application of manure at agronomic and environmentally responsible rates. However, the total amount of cultivated land in the entire study area is insufficient for agronomic disposal of all the manure potentially produced by existing ILO's. The potential for further expansion of the livestock-feeding industry in the study area is severely limited by the scarcity of cultivated land available for manure disposal.

A comprehensive, site-specific manure and nutrient management plan needs to be developed and implemented for each ILO. An appropriate set of management practices must be identified and adopted for the specific waste management system of each livestock-feeding enterprise. Consideration must be given to all aspects of waste collection, storage, land application and nutrient management. Rates for land application of manure must be based on crop nutrient requirements to minimize potential environmental contamination.

ACKNOWLEDGEMENTS

Partners in this project included Agriculture and Agri-Food Canada, Alberta Cattle Feeders' Association, Alberta Environmental Protection, Alberta Health, Barons-Eureka-Warner and City of Lethbridge Health Units, County of Lethbridge, Lethbridge Northern Irrigation District (LNID), Oldman River Regional Planning Commission and University of Alberta Hospitals.

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MANURE AND NUTRIENT MANAGEMENT TO SUSTAIN GROUNDWATER QUALITY IN ALBERTA

Barry M. Olson[1] and D. Rodney Bennett[1]

INTRODUCTION

Nitrate contamination of surface water and groundwater in Alberta has been attributed to a number of farming practices, including improper handling and disposal of manure (Bow River Water Quality Task Force 1991). Disposal of manure from large feedlots has been recognized as a growing problem, particularly in areas where high densities of sizeable operations exist and the availability of land for manure disposal is limited (Power and Schepers 1989). Runoff from feedlots and manure storage facilities poses the most serious threat to surface water (nitrate and phosphate pollution), whereas overloading of land with manure is the greatest concern for groundwater resources (nitrate pollution) in Alberta (Paterson and Lindwall 1992).

Chang et al. (1991) concluded that nitrate pollution problems may occur after annual applications of cattle manure at rates greater than or equal to existing Alberta guidelines for nonirrigated and irrigated land (maximum rates of about 30 and 60 Mg/ha, respectively). Subsequent monitoring of selected sites in southern Alberta revealed soil nitrates-N in excess of 200 kg/ha in the lower root zone and groundwater nitrate-N concentrations near 100 mg/l at three of seven sites investigated (Riddell and Rodvang 1992). Nitrate contamination of groundwater was most evident beneath sandy loam soils to which high rates (60 to 150 Mg/ha) of cattle manure had been applied annually for extended periods.

The overall objective of this four-year project is to develop improved manure and nutrient management practices to maximize the economic value of manure amendments and to minimize impacts on shallow groundwater quality. Amendment rate recommendations will be developed for manure disposal that optimize returns and minimize nitrate contamination of shallow groundwater. An awareness program will also be developed to communicate findings of this study to the cattle-feeding industry, producers, and the general public.

This study will promote effective management of manure from feedlots for optimum economic crop yield and protection of shallow groundwater quality. Increased awareness and implementation of best management practices for manure disposal will increase the profitability of the cattle-feeding industry through improvements in nutrient management. Adoption of best management practices will also minimize the impact of the industry on the environment.

Funding for this study is provided by the Proposal Based Research Program and the Water Quality Program of the Canada-Alberta Environmentally Sustainable Agriculture (CAESA) Agreement.

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METHODS

Southern Alberta Sites (Irrigated)

Two sites established in 1993 are located north of Lethbridge in the Lethbridge Northern Irrigation District. One site is on a medium-textured soil (loam to clay loam) and the other on a coarse-textured soil (loamy sand). Five blocks were established at each site. Each block contains one replicate of six main treatments in 16 m by 16 m plots. The main treatments are 0, 20, 40, 60, and 120 Mg/ha of wet manure, and 60 kg N/ha as urea fertilizer. The main treatments were split into two subtreatments. Half of the 0 Mg/ha manure and 60 kg N/ha fertilizer plots received 120 kg N/ha as urea fertilizer. Half of each manured plot was treated as a best management practice (BMP) relative to the nitrogen requirements of the crop estimated at 180 kg N/ha. Only the 20 Mg/ha plots required additional fertilizer in order to reach the level of the BMP estimate. Treatments were arranged in a randomized complete block design and were replicated five times (Figure 1).

One 3 m to 4.5 m long piezometer was installed near the centre of each subplot in the spring of 1993. The piezometers were slotted below 1 m. The drill holes were backfilled with sand to 1 m and with bentonite from 0.1 to 1 m. Groundwater was sampled monthly during the spring to fall season and was analysed for nitrate-N and chloride content. Three sample sets were also analysed for trace elements and coliform content in 1994.

Soil samples were taken in the fall of 1993 for baseline analysis. Samples were collected at 6 and 10 m along a transect down the centre of each subplot. A composite sample from the two profiles in each subplot were obtained at depths of 0 to 0.15, 0.15 to 0.3, 0.3 to 0.6, 0.6 to 0.9, 0.9 to 1.2 and 1.2 to 1.5 m. Soil analysis included extractable nitrate-N and ammonium-N, pH, electrical conductivity, soluble cations, and soluble anions.

Manure was applied annually in the fall of 1993 and 1994, and will be applied once more in the fall of 1995. Manure was incorporated immediately following application using a double disc. Five samples of manure were collected at each site at the time of application. Manure samples were analyzed for total organic carbon, total Kjeldahl nitrogen, and total and extractable phosphorus.

Neutron probe access tubes (1.5 m) were installed in each subplot in replicates one, three and five in the spring of 1994. Soil samples were collected in the spring of 1994 and analysed for extractable nitrogen content. Urea fertilizer was deep banded prior to seeding. The sites were seeded to barley (Hordeum vulgare L. 'Duke'). Phosphorus fertilizer (30 kg P_2O_5/ha) was applied with the seed at the medium-textured site. Barley was harvested as a silage crop by taking two, one square metre samples from each subplot. Subsamples were oven dried and the yields were calculated.

Soil samples were collected in the fall of 1994 prior to the second manure application and analysed as previously described.

Both sites were irrigated with solid-set irrigation systems. Water was applied at a rate of 10 mm/h for five hours for a total application of 50 mm per irrigation event. Irrigation water was applied to the entire area when available soil moisture within the upper 0.5 m of the profile was depleted to 50 percent of available water holding

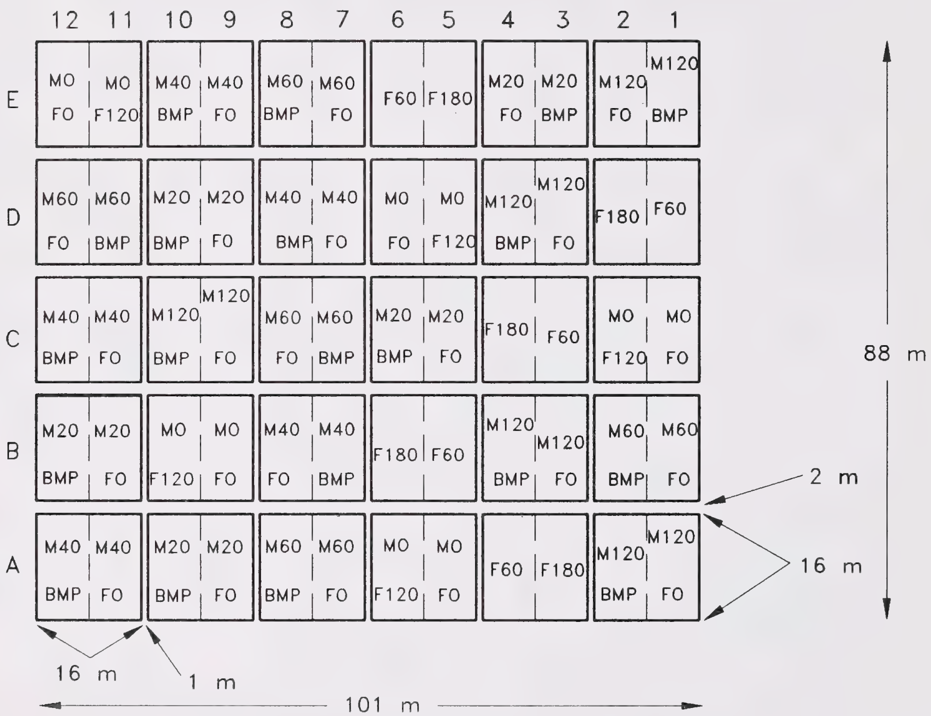

Figure 1. Experimental design and plot arrangement. Treatments were re-randomized at each site.

capacity in the 180 kg/ha N fertilizer subtreatment.

Central Alberta Sites (Dryland)

Two sites were established in central Alberta in 1994: one near Ponoka on a loam soil and one near Lacombe on a silty clay loam soil. The experimental design is the same as described for the southern sites. Piezometers (8 to 9 m) were installed in each subplot in replicates one, three, and five. Groundwater samples were collected in July, August and September and analysed for nitrate-N and chloride contents. Soil samples were collected for baseline analysis and manure was applied and incorporated in the fall. The nitrogen fertilizer treatments will be applied in the spring of 1995 and the sites seeded to barley. The sites will be managed under dryland conditions.

PRELIMINARY RESULTS

Southern Alberta Sites (Irrigated)

High rates of manure resulted in a slight increase in soil nitrate-N from 0 to 0.15 m in the medium-textured soil in 1994, with no significant differences at the lower depths (Figure 2). Nitrate-N content of the coarse-textured soil was significantly higher with high rates of manure and fertilizer, and total nitrate-N within the soil profile was high, even in the control treatment (Figure 2).

Groundwater nitrate-N content was spactially variable beneath the sites, with mean treatment values ranging from 1 to 15 mg/l at the medium-textured site and from 10 to 60 mg/l at the coarse-textured site in 1993 (i.e. post-treatment baseline samples).

Results in 1994 showed no clear treatment effects on groundwater nitrate-N concentrations. However, among the manure treatments at the coarse-textured site, the 120 Mg/ha rated tended to have the highest groundwater nitrate-N concentrations (Figure 3).

No significant differences in silage barley yield were detected among all subtreatments at both sites in 1994.

Central Alberta Sites (Dryland)

Only baseline soil and groundwater data were collected at the central Alberta sites during 1994. Baseline soil nitrate-N and ammonium-N concentration ranges were 0 to 20 mg/kg and 3 to 32 mg/kg, respectively, at the loam site, and 0 to 26 mg/kg and 2 to 21 mg/kg, respectively, at the silty clay loam site. The groundwater nitrate-N concentrations were below 10 mg/l at both sites, with most samples below the detection limit. The first post-treatment data will be collected in 1995.

SUMMARY

A field study was initiated to evaluate manure and nutrient management practices regarding groundwater quality. Two irrigated sites where established in southern Alberta in 1993, and two dryland sites were established in central Alberta in 1994. Only one season of post-treatment (manure and nitrogen fertilizer treatments) data

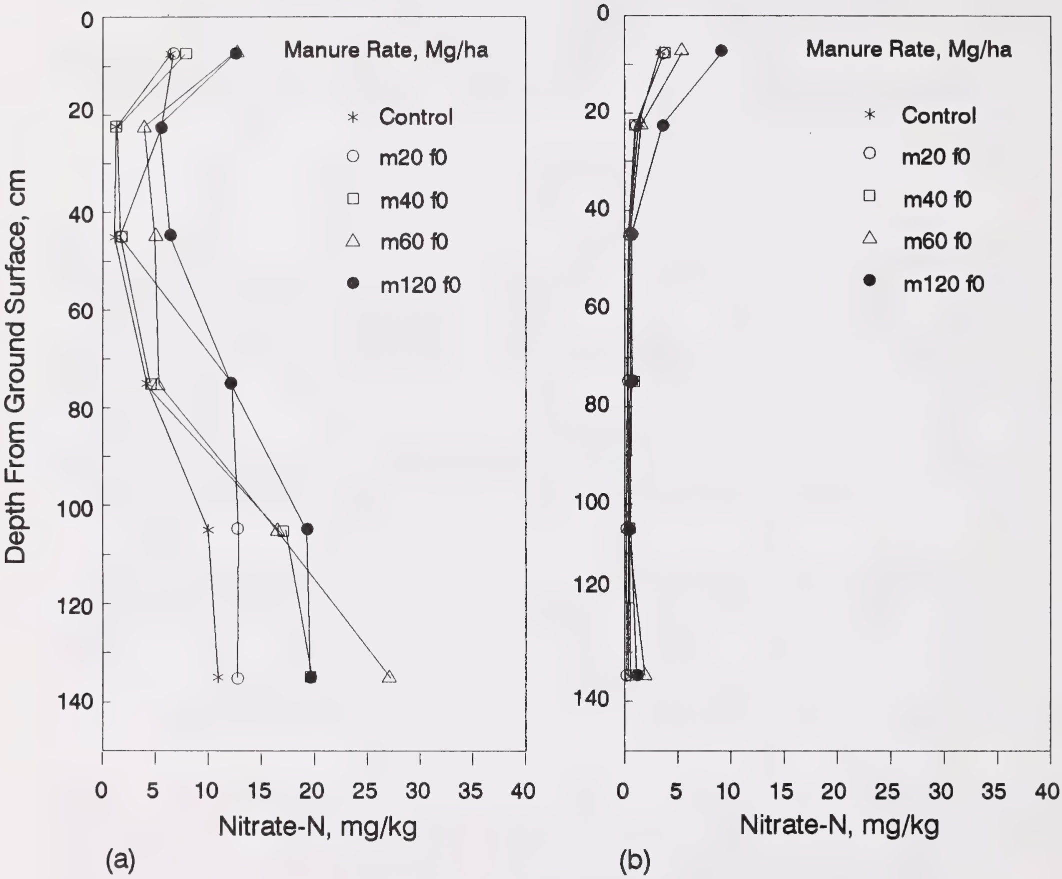

Figure 2. Nitrate-N content in the soil profile at the coarse-textured (a) and medium-textured (b) sites in southern Alberta.

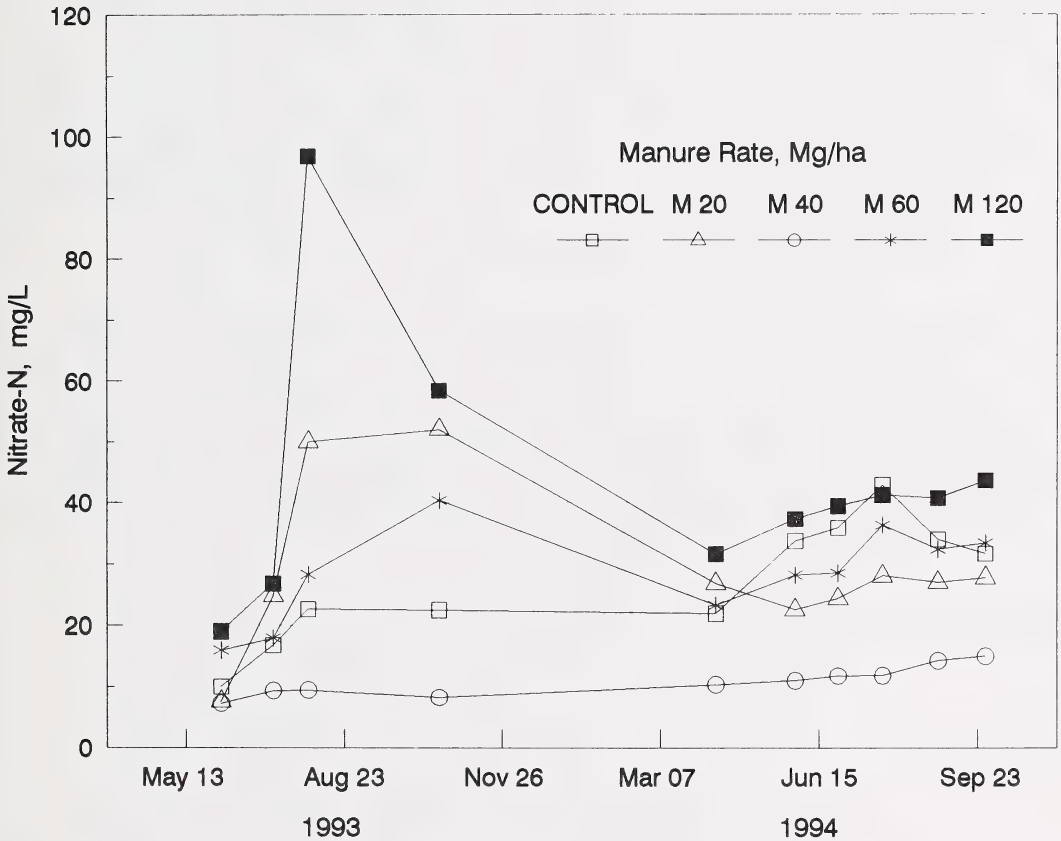

Figure 3. Nitrate-N concentration in the groundwater at the southern Alberta coarse-textured site.

have been collected at the southern Alberta sites. The field experiment will continue for two more growing seasons (1995 and 1996).

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GROUNDWATER RETURN FLOW IN THE LETHBRIDGE NORTHERN IRRIGATION DISTRICT

S. Joan Rodvang[1] and D. Rodney Bennett[1]

INTRODUCTION

Nitrate from fertilizer and manure has resulted in groundwater contamination in some areas of North America (Spalding and Exner 1993). The Battersea drainage basin of the Lethbridge Northern Irrigation District is an area with intensive irrigated agriculture. The basin also has one of the highest densities of intensive livestock and poultry feeding operations in Alberta. A three-year groundwater investigation was initiated in 1994 to: 1) characterize the existing groundwater conditions in the Battersea basin, including flow and quality, and 2) predict the effect of excess nitrate on groundwater and surface water quality over the long term.

METHODS

Piezometer nests were installed at 23 locations along a transect between the eastern edge of Blackspring Ridge and the Oldman River (Figure 1). Geology was described during drilling.

Groundwater samples were collected from the piezometers, drain effluent and groundwater seepage areas (Figure 1). Thirty domestic wells in the Battersea basin were sampled three times in 1994, and the groundwater chemistry was compared to that measured in 28 domestic wells sampled between 1958 and 1986 (Figure 1).

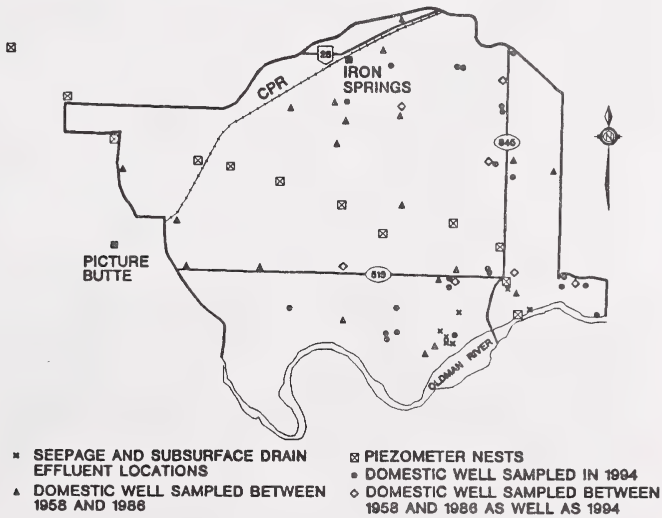

Figure 1. Location of piezometer nests, domestic wells and seeps in the Battersea drainage basin.

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PRELIMINARY RESULTS AND DISCUSSION

Geology in the study area consists of 75 to 125 m of glacial- and post-glacial deposits over bedrock. Glacial till is overlain by up to 17 m of coarse to fine lacustrine sediments (Figure 2), which have provided a water supply to farms in the area since the early 1900's. The wells are generally less than 10 m below ground surface, and the majority contain less than 1500 ppm total dissolved solids (TDS).

The water table is approximately 50-m below ground at the NW end of the cross section, increasing to less than 3.5-m below ground in the lacustrine basin (Figure 2). Groundwater flows from Blackspring Ridge towards the Oldman River, although the very flat gradient in the lacustrine basin results in gradient reversals at many locations. Preliminary results suggest groundwater flow is very slow through the reduced till and bedrock (Figure 2).

Groundwater nitrate (up to 90 ppm NO_3^--N) occurred at several locations near the water table in the lacustrine basin. Preliminary results suggest this nitrate was related to agricultural sources.

Several factors suggest denitrification may be removing nitrate from groundwater in the lacustrine basin. Nitrate generally decreased to zero a short distance below the water table in the basin, and the disappearance did not correspond to geologic barriers to downward groundwater flow. At piezometer-nest 8, high levels of chloride persisted to a depth of 9 m, even though nitrate was not detected below 3 m (Figure 3). This pattern is consistent with downward leaching of nitrate and chloride from manure, and removal of nitrate via denitrification below 3 m. The odour of hydrogen sulfide was commonly detected at depths of 4 to 75 m below the water table in the lacustrine basin (Figures 2 and 3), indicating conditions at those depths were sufficiently reducing for denitrification to occur.

Groundwater nitrate (up to 300 ppm) occurred at some locations in till and fine lacustrine deposits in mid- and upper-slope locations. This nitrate was not always associated with the occurrence of nitrate at the water table (Figure 4). The highest levels of nitrate were detected between 6 and 13 m.

Shallow groundwater from coarse and medium-textured lacustrine deposits discharges to the river at relatively high rates. Subsurface drainage also transports shallow groundwater to the river at some locations. Nitrate was over 1 ppm (up to 16 ppm) in five of the seven seepage locations sampled (Figure 5).

Water in some of the domestic wells sampled in 1994 approached or exceeded the Canadian drinking water guideline for nitrate (Figure 6). Many (but not all) of the wells with high nitrate were located near feedlots. All domestic wells sampled between 1981 and 1986 exhibited less than 10 ppm NO_3-N (Figure 6). The apparent increase in nitrate between 1986 and 1994 may be due to differences in sampling locations, and/or sampling/analytical methods. Major-ion concentrations were similar in the two data sets.

Most domestic wells sampled in August of 1994 had no coliform, but a few samples exceeded the drinking water guidelines for coliform (Figure 7). Nitrate levels were not highly correlated with coliform detection. Malard et al. (1994) found coliform-leaching was enhanced by fracture flow.

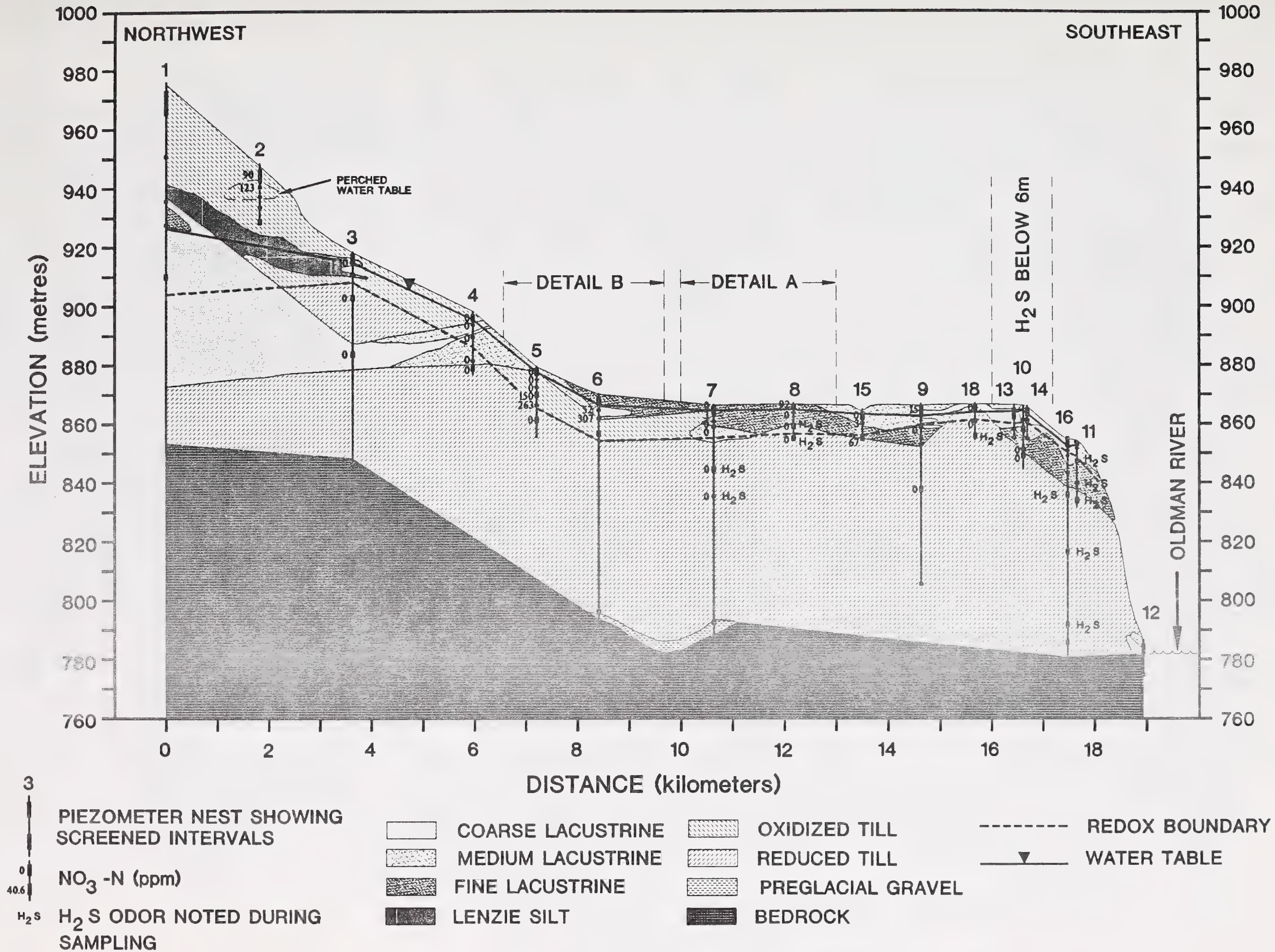

Figure 2. Geologic cross section through the Battersea drainage basin.

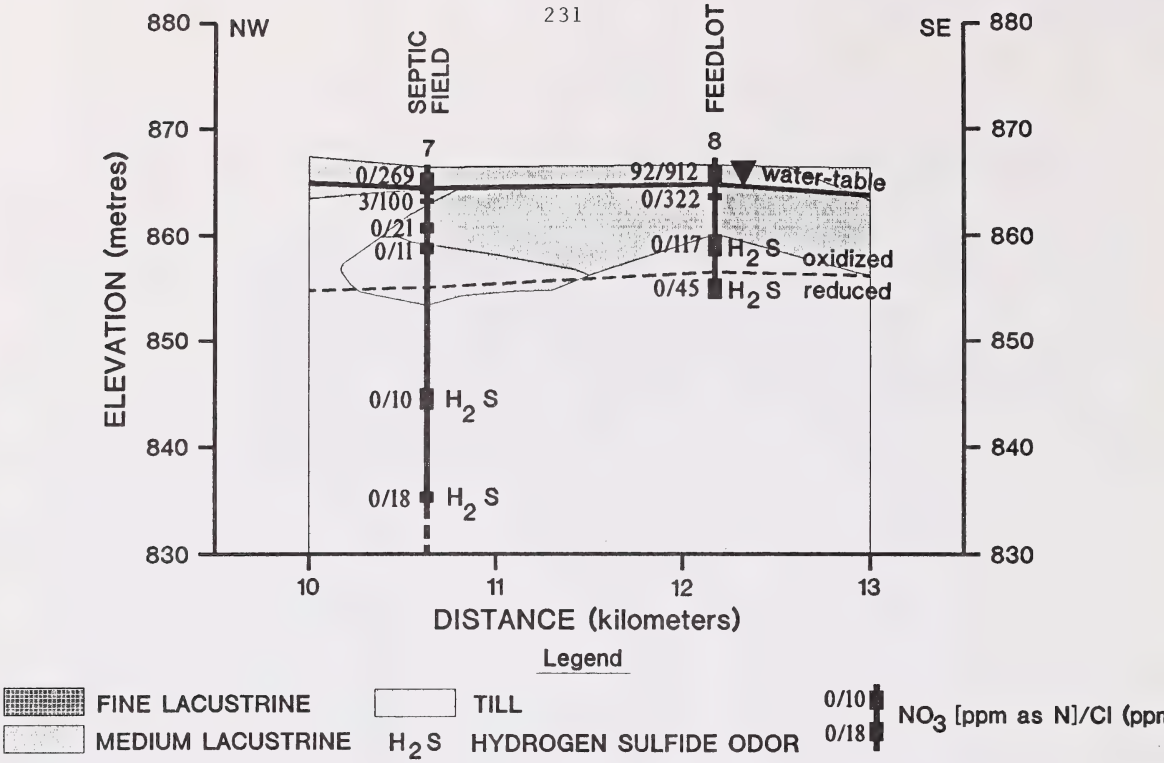

Figure 3. Geologic cross section along Detail A.

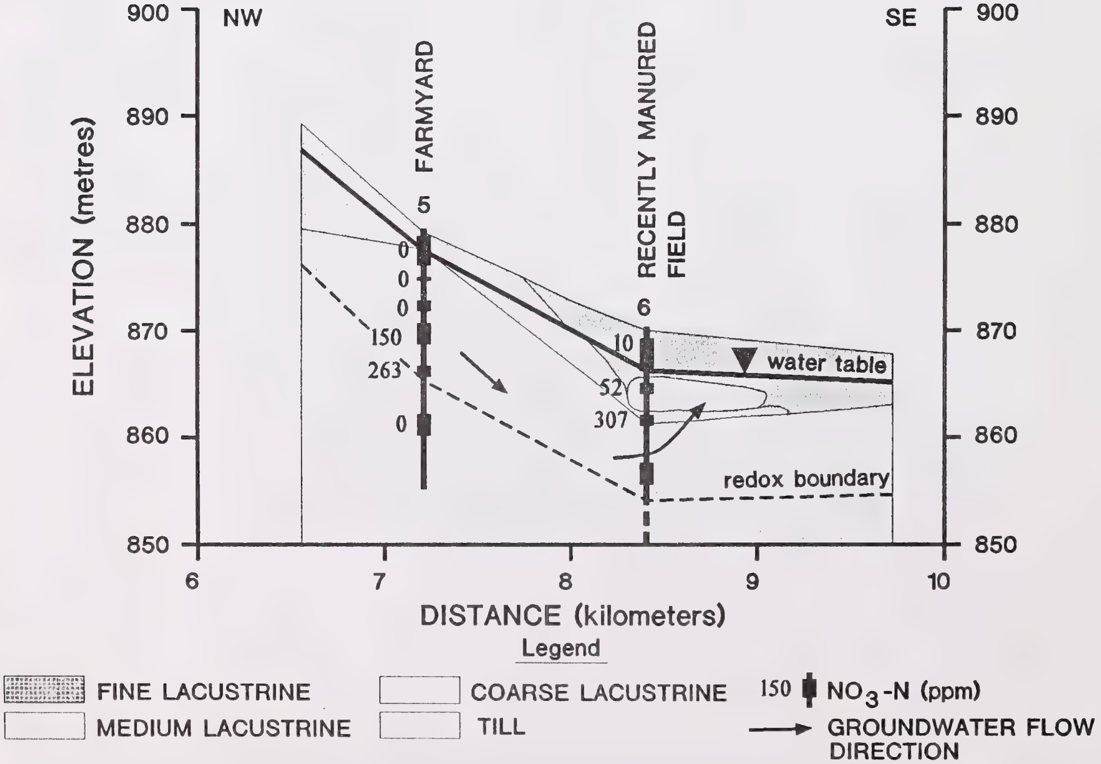

Figure 4. Hydrogeologic cross section along Detail B.

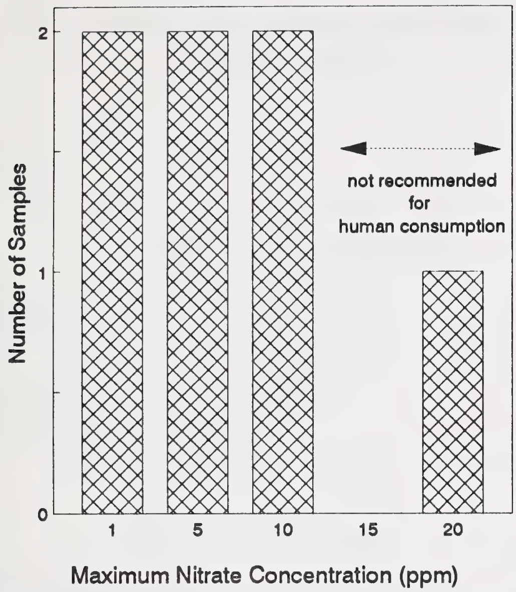

Fig. 5. Nitrate distribution in groundwater seeps and subsurface drain effluent along the Oldman River, October 1994.

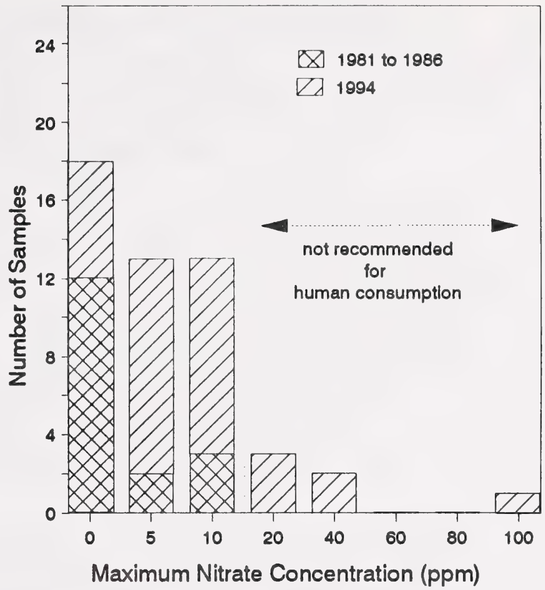

Fig. 6. Nitrate distribution in domestic wells.

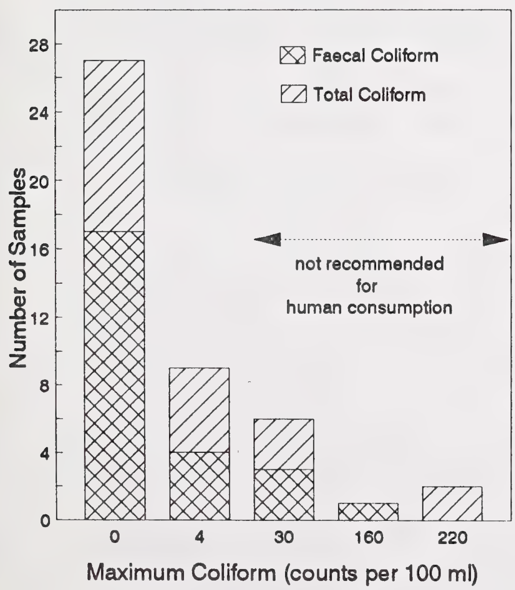

Fig. 7. Coliform in domestic wells, summer 1994.

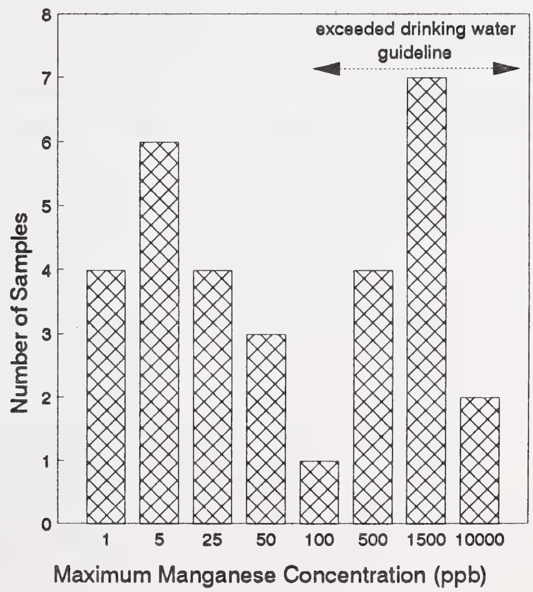

Fig. 8. Distribution of manganese in domestic wells, August 1994.

Manganese exceeded drinking water guidelines in many of the domestic wells (Figure 8). The presence of dissolved manganese indicates conditions were reducing enough for denitrification to occur. Manganese may be acting as an electron donor for denitrification (Korom 1992).

PRELIMINARY CONCLUSIONS

The surficial silt and sand aquifer in the Battersea basin is relatively susceptible to contamination from the surface. The effect of return flow from the aquifer to the river requires further investigation.

Preliminary results suggest agricultural nitrate is present near the water table at some locations in the lacustrine basin. Most nitrate levels were low, but levels of up to ten times the drinking-water guideline were detected. Denitrification may remove nitrate from groundwater in the lacustrine basin, at depths as shallow as 1.5 m below the water table. Sampling of groundwater seeps and subsurface drain effluent suggests denitrification was not effective in removing all nitrate from groundwater at shallow depths.

High levels of nitrate were detected between 6 and 13 m depth in fine lacustrine and till deposits along the flanks of the ridge. Preliminary evidence indicates this may not be agricultural nitrate, since it did not tend to be associated with elevated nitrate near the water table.

Domestic wells at some locations contained more nitrate, coliform and manganese than recommended for human consumption.

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NITRATE MIGRATION UNDER LONG-TERM IRRIGATED FIELDS

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INTRODUCTION

A CAESA-funded investigation of groundwater nitrate below fertilized and irrigated fields in southern Alberta was initiated in 1993. The investigation will provide further knowledge about: 1) the factors which affect the distribution of nitrate in groundwater, and 2) the potential for agricultural nitrate contamination of groundwater on the prairies. Both are poorly understood at present (Spalding and Exner 1993, Morrison and Kraft 1994).

METHODS

Groundwater was sampled throughout an intensively fertilized and irrigated sub-basin of the Bow River using an existing network of piezometers (Hendry et al. 1984) and also at three additional fertilized and irrigated locations, called the detailed sites (Table 1). Piezometers in the basin-scale study area were located adjacent to cropped fields, whereas piezometers at the detailed sites were located on cropped fields unless otherwise noted.

Water levels were read monthly in all piezometers, and twice monthly at the detailed sites during the summer months.

Groundwater samples were collected from all piezometers in August, 1994 for major ions, iron, manganese, copper, nitrate, ammonium, pH, temperature and dissolved oxygen. Piezometers at the detailed sites were sampled monthly for nitrate, chloride and ammonium. Groundwater samples for tritium analysis were collected from all piezometers in February, 1994 with repeat analysis in October, 1994. Tritium was analysed at the Environmental Isotope laboratory in Vegreville, Alberta. Samples for oxygen ($^{18}O/^{16}O$) isotope fractionation analysis were taken in the fall of 1994 from all piezometers at the detailed sites and selected nests in the basin. Samples were analysed at the National Hydrology Research Institute laboratory in Saskatoon.

Soil samples were collected to depths of 3 to 6 m from the detailed sites in the spring and fall of 1994. Nitrate and ammonium were determined on 10:1 KCl extracts prepared on the day of collection. Chloride was determined on 1:1 water extracts.

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All nitrate results are reported as ppm NO_3^--N.

RESULTS AND DISCUSSION

Basin-Scale Study

Fall 1994 nitrate patterns were similar to those observed in Fall 1993 (Schmidt-Bellach et al. 1994) and in 1980 (Hendry et al. 1984). Groundwater nitrate, above the drinking water guideline (10 ppm), occurred in 12 of 18 piezometer nests sampled. The highest nitrate (200 to 500 ppm NO_3-N) tended to occur about 6 to 20 m below ground in the weathered till and shallow bedrock. Tritium analysis indicated that groundwater at these locations recharged before 1953. Nitrate was detected at the water table in the flattest portion of the basin. The water table at these locations was deeper than the average 2 or 3 metres below ground surface. Tritium analysis suggests this water had recharged since 1953.

Nitrate was less than 10 ppm in the bedrock, except at a few locations, where nitrate ranged from 100 to 400 ppm. These levels were restricted to the upper 5 m of the sandstone bedrock and where the till above was weathered and less than 22 m thick. A sandy loam layer at the base of the weathered till at these locations may have provided a hydraulic connection to the bedrock. Ammonium was generally detected below 15 m, and where nitrate levels were below 5 ppm. Ammonium also occurred at some locations where nitrate levels were above 100 ppm.

Detailed Site 1

Piezometer depths ranged from 1.5 to 20 m. Logging of test-holes to the north and south of Site 1 suggested sandy water-conducting layers occurring at depths between 12 and 18 m within the till may pinch out beneath Site 1. Discharge gradients were encountered throughout the site (Figure 1). The strongest discharge gradient occurred at the south end, possibly caused by the pinching out of sandy layers.

Tritium was not detected below 3 to 6 m (Figure 1). The shallow till probably restricts infiltration, and upward gradients introduce pre-1953 groundwater from below. Preliminary one-dimensional recharge rates could only be determined from shallow tritium values at location 3, as upward gradients were observed at all other locations. Recharge calculations based on both the depth of peak tritium values and the depth where tritium disappears, determined overall recharge rates of 2.1 to 3.2 cm yr^{-1}.

Groundwater nitrate was consistently over 400 and 100 ppm NO_3-N at the north and south ends of the property, respectively, (locations 4 and 1), extending to depths of 11 to 13 m (Figure 1). Low hydraulic gradients and negligible plume movement have been detected since monitoring began. Nitrate in all piezometers at location 4 showed similar trends with time. Nitrate ranged from 160 to 358 ppm in January, increasing to 192 to 514 ppm in August, before dropping again in early 1995 to 211 to 458 ppm (Figure 2). Concentrations at location 1 remained stable throughout the year. Upward gradients at both locations suggest the plumes may be derived from below (Figure 1).

Chloride trends remained constant during 1994, with the highest values

occurring just above nitrate peaks.

Evidence for denitrification was generally lacking. Dissolved oxygen was greater than 1.0 ppm, iron and manganese were low (< 0.3 and 0.14 ppm respectively), and chloride/nitrate molar ratios ranged from only 0.1 to 10. The only exceptions were at locations 3 and 6, at 4 m depth. At these locations, chloride/nitrate molar ratios exceeded 1000, iron and manganese appeared in solution at 9-m depth, and nitrate was not detected below 9 m. Dissolved oxygen was low at location 6.

Soil nitrate patterns were similar to groundwater nitrate patterns, but soil values were often ten times less than groundwater values. Soil nitrate concentrations above the water table were at or below 10 ppm.

<u>Detailed Site 2</u>

Piezometers depths ranged from 1.4 to 9.5 m. Sites 7 and 8 were located on an unfertilized dirt trail at the edge of the study area. Vertical potentiometric contours over most of the site showed little or no groundwater flow into the deeper till.

Tritium was detected to a depth of at least 9 m, but high values (30 to 62 TU) were observed only in the lacustrine sands. Values dropped below 5 TU at a depth of 1.5 to 3 m below the sand-till contact (Figure 3), indicating that much of the post-1953 groundwater recharge circulated within the lacustrine sands and shallow till at location 3. Preliminary one-dimensional recharge calculations based on the tritium peak and near extinction methods indicated recharge rates of 2 to 4 cm yr^{-1} for the till, and 6 cm yr^{-1} for the lacustrine sands.

Isotopic ratios of oxygen-18 to oxygen-16 decreased smoothly with depth, ranging from -14.6 to -16.6 near the water table to -21.8 at depths of 5 to 8 m. The decrease with depth suggests ^{18}O enrichment due to evaporation from the shallow water table.

Peak soil nitrate concentrations ranged from 41 to 145 ppm under the potato plots and from 62 to 107 ppm under the corn. Maximum concentrations generally occurred at or just above the water table. Location 7 peaked at only 16 ppm. Between the depths of 3.5 and 5 m, soil nitrate dropped below 1 ppm and ammonium rose above 1 ppm. The exception was at location 6, where ammonium was above 1 ppm at 2 m depth, and nitrate remained above 1 ppm throughout the sample profile.

Groundwater nitrate near the water table tended to increase immediately following rain or irrigation. The highest nitrate concentration occurred with the first irrigation and rain after crop fertilization in the spring (Figure 4). With the exception of locations 1 and 7, groundwater nitrate peaked with precipitation after harvest. This suggests that unused nitrate in the root zone was flushed into the groundwater. The nitrate at location 8 may have been derived from groundwater flow from the cropped field.

Groundwater nitrate levels decreased with depth, and dropped below 10 ppm at depths of 3 to 4 m (Figure 3). Chloride concentrations (ranging from 50 to 500 ppm) also decreased with depth. Exceptions were found at locations 7 and 8, where chloride levels were at or above the drinking water guideline (250 ppm) and nitrate values were below 10 ppm. Denitrification may be responsible for the decrease in

nitrate with depth, consistent with the following observations: 1) the decrease in nitrate corresponded to a decrease in dissolved oxygen and an increase in chloride/nitrate molar ratios, and 2) dissolved iron, manganese and ammonium were detected where nitrate dissappeared (Figure 3). Starr and Gillham (1989) found greater rates of denitrification at sites with shallow water tables, as more organic carbon would be available for the process than at depth.

Detailed Site 3

Piezometer depths ranged from 1.5 to 4.1 m. Different fertilizer rates were represented by piezometer nests in three different plots, and water-table wells were installed at strategic locations around the perimeter of the site.

Tritium values decreased from 30 TU at the water table to below 5 TU at 3.5-m depth, indicating that the shallow groundwater recharged after 1953. Isotopic oxygen ratios ($^{18}O/^{16}O$) could only be analysed for the 4-m deep piezometers at this site. Ratios ranged from -14.7 to -17.4 and were highest at the northwest corner of the study area.

Soil nitrate concentrations, averaged for each fertilizer application rate, were proportional to those rates (Figure 5). The largest range in soil nitrate occurred under the 200 and 50 kg N ha^{-1} plots, probably due to stratigraphic controls. Ammonium ranged from 0.4 to 4.0 ppm NH_4-N throughout all the profiles, but did not appear to increase with higher nitrate concentrations.

The highest groundwater nitrate concentrations were encountered at plots that either received, or were adjacent to plots that received, 100 or 200 kg N h^{-1} annually. Groundwater nitrates, averaged for the four different application rates, were approximately proportional to their fertilizer application rates, although plots that were unfertilized showed nitrate levels similar to plots that received 100 kg N h^{-1} (Figure 6). This may be due to lateral groundwater flow from adjacent plots with different application rates. Soil and groundwater nitrate levels compared best under plots with 100 and 200 kg N ha^{-1} application rates. Elsewhere, groundwater nitrates were generally higher, also suggesting lateral flow of nitrate in groundwater. The five piezometers with nitrate levels below 10 ppm exhibited the lowest hydraulic conductivities, rather than the lowest fertilizer application rates.

Site 3 showed no evidence for denitrification. Molar chloride-nitrate ratios ranged from 0.03 to 8, and tended to increase with depth. Dissolved oxygen values decreased with depth, but remained above 0.5 ppm (most ranged from 1.0 to 10 ppm). Low ammonium levels (>0.3 ppm) were periodically detected in all piezometers, but showed no distinctive pattern. Iron and manganese levels were at or just above the detection limit in all piezometers.

PRELIMINARY CONCLUSIONS

Elevated groundwater nitrate (up to 500 ppm) occurred at several locations in the weathered till and shallow bedrock throughout the basin and at a detailed site located within the basin (Site 1). Tritium results indicate this nitrate was derived from a pre-1953 source. Evidence for denitrification was generally lacking in the basin, with the exception of one of 8 monitoring locations at Detailed Site 1.

Site 2 showed lateral groundwater nitrate migration through shallow lacustrine sands during 1994. Geochemical evidence suggested denitrification was responsible for the disappearance of nitrate just below the sand/till contact.

At site 3, elevated soil and groundwater nitrate was concentrated below plots receiving the highest fertilizer application rates (100 to 200 kg N ha^{-1}), and nitrate tended to decrease with depth. Horizontal groundwater movement was restricted by low hydraulic conductivity areas in the till. However, lateral flow may have influenced the nitrate values at plots where no fertilizer was applied.

Sites 1 and 3 showed a significant discrepancy between soil and groundwater nitrate concentrations, which suggests fractures influenced groundwater recharge and flow. Recharge rates based on tritium ranged from 2 to 6 cm yr^{-1}.

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Table 1. Characteristics of the Basin and Three Detailed Sites

Site	Land Location	Crops & Yield (t/ha)	Fert. Rate (kg/ha)	Geology	Hydraulic K (m/s)	Water Table Depth (m bgs)	Groundwater dir.& horz. gradient (dir & %)
Basin	NNE of Vauxhall in BRID	Wheat, barley, peas, alfalfa, potatoes, hay, beans, beets, canola & corn.	--	Overburden thickness = 12-46 m Oxid. till thickness = 18-32 m Unox. till thickness = 0-28 m Bedrock made up of interbedded sandstone, shale, claystone & siltstone.	oxid. till 5x10-8 unox. till 3x10-8 sandstone 4x10-8 shale 1x10-8	depth range= 2 to 13 m average = 2 to 5 m	N to NNW 0.4-3.7%
1 Private Landowner	Near the centre of the study area.	Wheat@10.7 t/ha and alfalfa	N = 100 P205=22	Aeolian & lacustrine deposits are 0.5 - 1.5 m thick. Oxid. till thickness = 20 m sitting on bedrock.	Shallow till 2x10-7 Deeper till 2x10-8	seasonal fluct. of 2 to 3 m	NNW @ 0.2%
2 Vauxhall Station	SE4-13-16 W4	Potatoes gross at 49 t/ha market@42 t/ha Corn (wet wt.) cob at 42 t/ha Corn (wet wt.) silage@45 t/ha	N = 112 P205=112	Lacustrine sandy loam to sand ranging 0.5(E)-6(W) m thick above till.	Lacust. SL-S 9x10-6 Till= 2x10-8	seasonal fluct. of 1-1.7 m	Summer: E 0.2 % Winter: WSW 0.2 %
3 Lethbdge. Research Station	NW34-8-21 W4	Oats	N of 0, 50, 100 and 200 selected plots.	Aeolian & lacustrine deposits of 0 - 1.2 m thickness above till.	Till ranged 3x10-6 to 5x10-9. Mean=1x10-7	seasonal fluct. of 1 to 2 m	Summer: E 1.0 % Winter: E&W 0.4% (N-S gw divide)

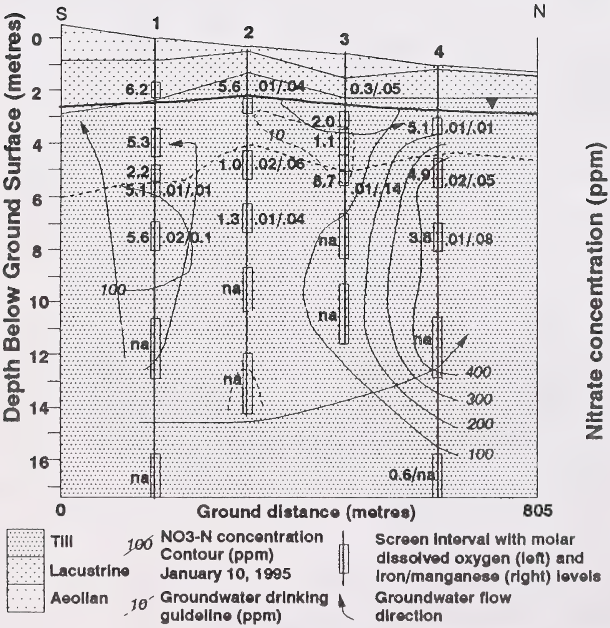

Fig. 1. Nitrate levels at site 1.

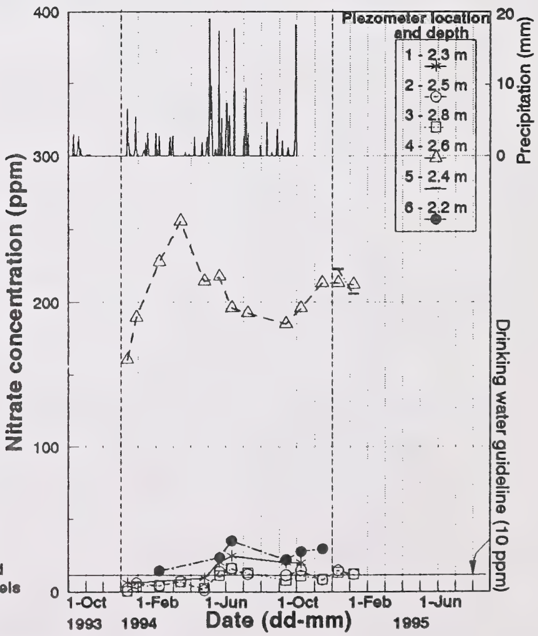

Fig. 2. Shallow groundwater nitrate levels, site 1

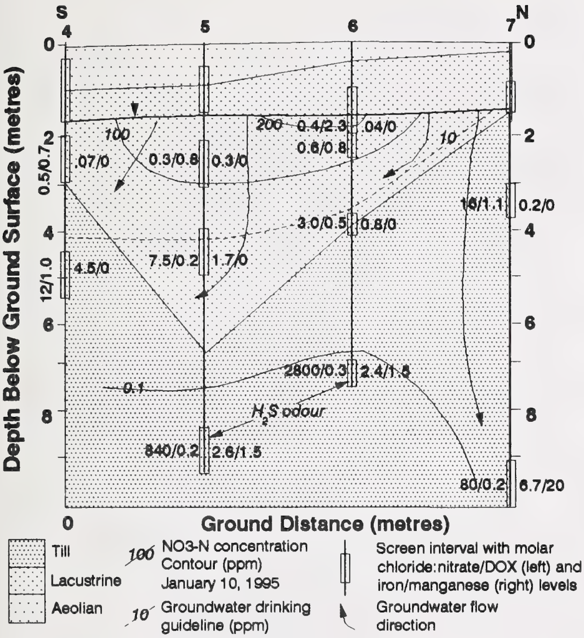

Fig. 3. Nitrate levels at site 2.

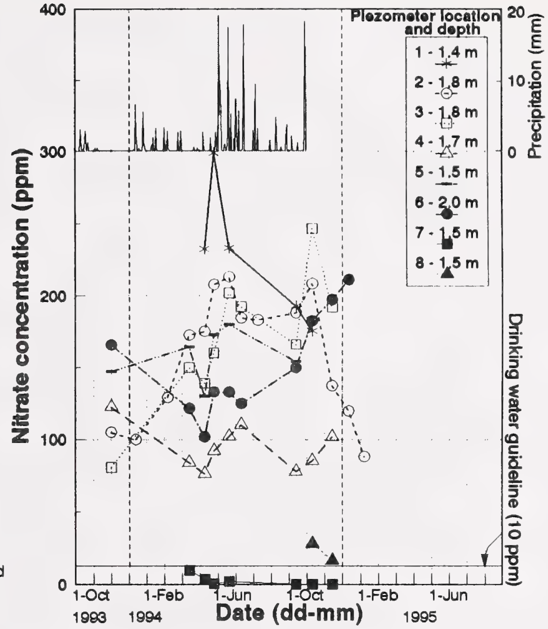

Fig. 4. Shallow groundwater nitrate levels, site 2.

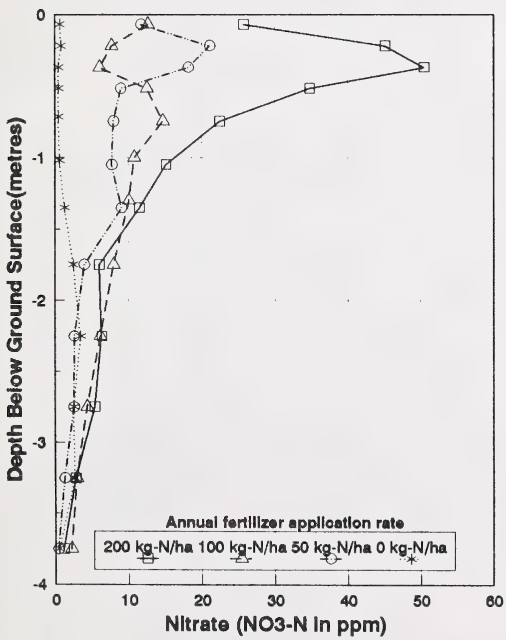

Fig. 5. Average soil nitrate levels at site 3 (Fall 1994).

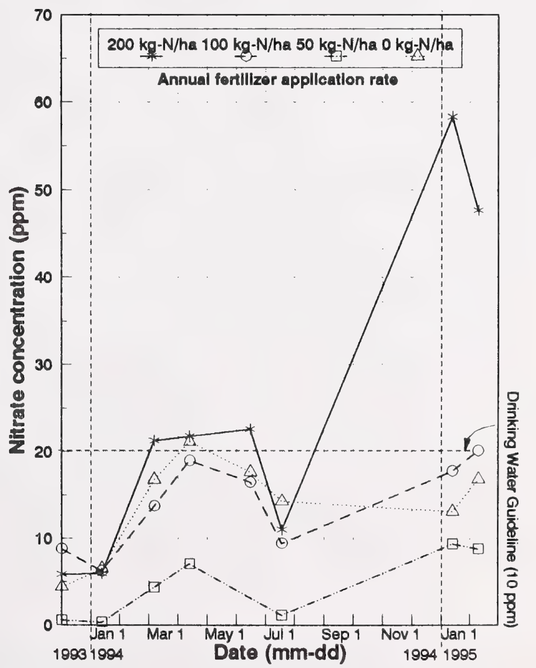

Fig. 6. Average groundwater nitrate at site 3,

IRRIGATION BLOCK STUDIES - SURFACE WATER QUALITY (YEAR ONE -1994)

G. M. Greenlee, P.Ag and P.D. Lund[1]

INTRODUCTION

Alberta announced in 1990 a water management policy for the South Saskatchewan River Basin that established guidelines for irrigation expansion. The announcement stated "these guidelines for limiting irrigation expansion will be reviewed in the year 2000." Accurate and complete information regarding water supply, crop water use and return flow volumes and water quality is required by the irrigation districts, to make proper water management decisions.

Concern about the impact of agriculture on surface and groundwater quality throughout Canada and the world has increased interest in evaluating possible water quality problems in Alberta's agricultural areas (Paterson 1991). The Bow River Water Quality Task Force (1991) cited irrigation return flows as a direct source of pollutants into the Bow River and its tributaries.

The quality of water used in the irrigation districts of southern Alberta is considered excellent, with average salinity levels from 0.32 to 0.36 dS m^{-1}, average sodicity levels from 0.17 to 0.61 and average total dissolved solids from 174 to 212 mg L^{-1} (Hamilton et al. 1982). Irrigation water is derived primarily from southern Alberta's major rivers which originate as snow-melt in the Rocky Mountains.

The objective of this study is to assess the quality of water entering and leaving two irrigation blocks, and returning to the rivers. The study is part of an irrigation block study initiated to quantify the amount and quality of water entering and leaving two irrigation blocks.

METHODS

The first two years of this four-year block study will function as baseline years to observe how the irrigation districts operate their delivery systems. Data gathered will be used to calibrate an irrigation district model, which will in turn be used to help develop improved water management strategies. These strategies will be given to the irrigation districts for implementation in the final two years of the study. Improved water conservation may result in reduced quantities of irrigation return flow water and changes in surface water quality. The information gathered in the block study will be critical to the review of irrigation expansion guidelines.

The two irrigation blocks studied are located in the Lethbridge Northern Irrigation District (LNID) and the Bow River Irrigation District (BRID) (Fig. 1, Fig. 2). Surface water quality monitoring sites for the LNID included the inlet and outlet of Keho Lake, the inflow and outflow of the irrigation block and the Battersea Drain return flow stream. Monitoring sites for the BRID included the inlet of McGregor

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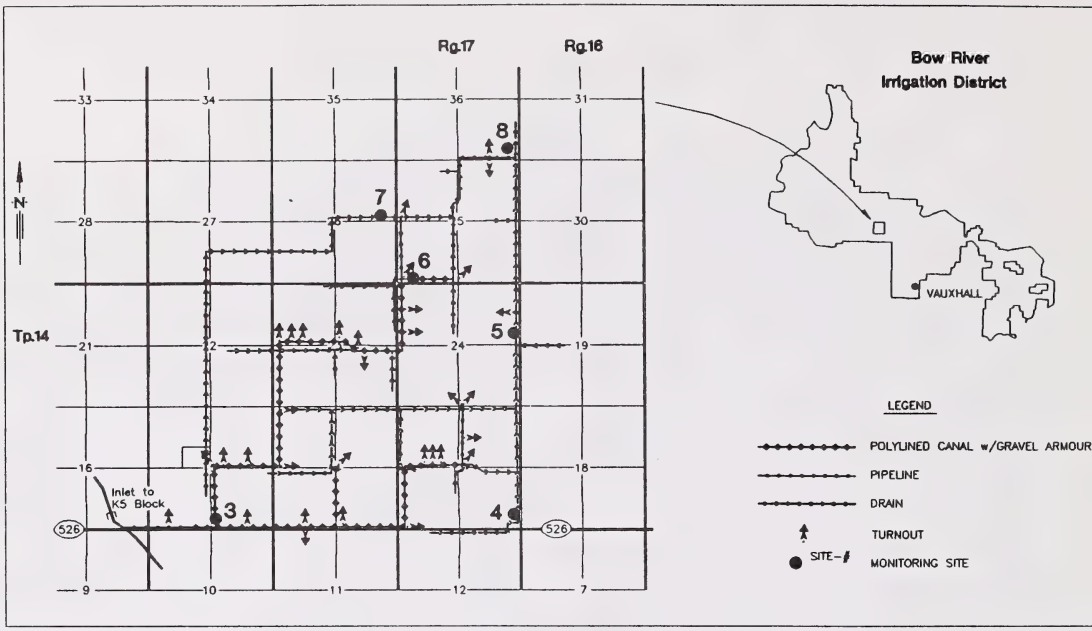
Figure 1. Surface water quality monitoring sites and mean daily water discharge monitoring sites.



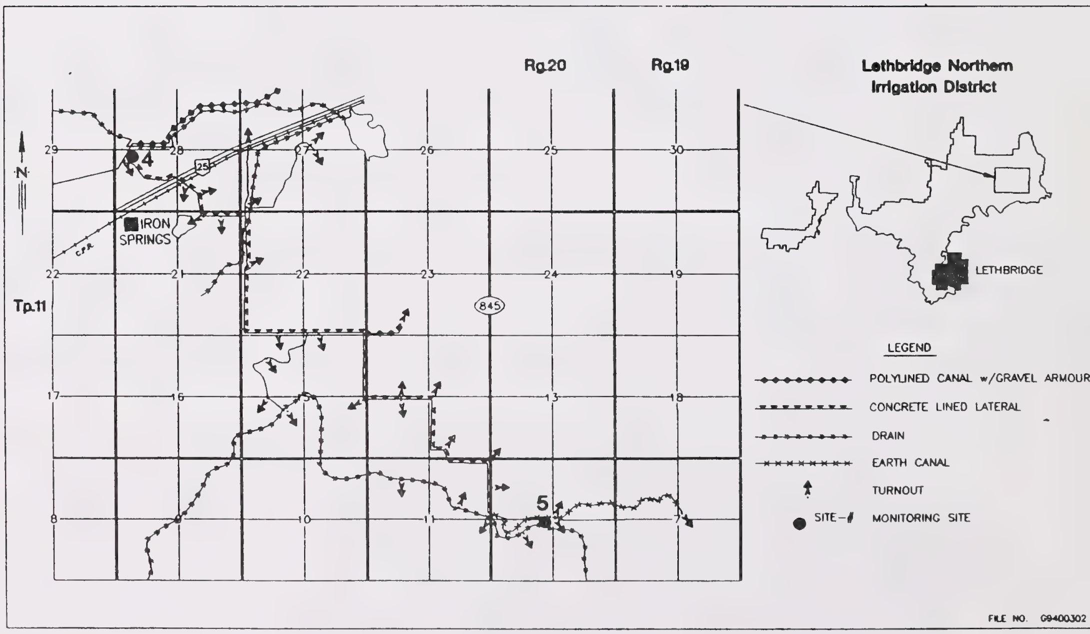


Figure 2. Location of irrigation block studies and surface water quality monitoring sites.

Lake (reservoir), the outlet of Little Bow Lake (reservoir), the inflow and outflow of the irrigation block, four drains entering the block and the New West Coulee return flow stream.

Surface water samples were collected weekly from May 11 through October 11 in the LNID, and from May 10 through September 26 in the BRID. Samples were collected twice in the BRID during the week of May 16 through May 22 due to a storm runoff event. Automatic surface water (ISCO) samplers were placed at the head and tail of the BRID block (sites 3 and 8). Composite samples were collected from the ISCO samplers on each sampling day from May 10 through September 7. Each composite sample consisted of 12 subsamples collected at 2-hour intervals and combined over the 24-hour period preceding the sampling day. All other water samples collected throughout the sampling period were individual grab samples.

Water samples were filtered and analyzed for pH, electrical conductivity (EC), soluble cations (calcium, magnesium, sodium, potassium), soluble anions (sulfate, chloride, carbonate, bicarbonate, nitrate, phosphate), total and faecal coliforms using standard analytical techniques (Greenberg et al. 1992). Nitrate was determined using the Technicon Traacs 800 Industrial Method No. 782-86T. Sodium adsorption ratio (SAR) and total dissolved solids (TDS) were calculated. Water samples were also analyzed for five trace elements (arsenic, cadmium, copper, lead, selenium) using atomic absorption spectrometry.

RESULTS AND DISCUSSION

LNID

Salinity, Sodicity and TDS: Average salinity and TDS levels increased slightly between the inlet and outlet of Keho Lake, did not change between the inflow and outflow sites of the irrigation block, and increased slightly in the Battersea Drain return flow stream (Table 1, Fig. 3). Average sodicity levels doubled between the inlet and outlet of Keho Lake, did not change between the block inflow and outflow sites, and increased slightly in the Battersea Drain return flow stream. The TDS level in the Battersea Drain return flow stream slightly exceeded the Canadian water quality guideline for human consumption (Table 2) on May 11 (678 mg L^{-1}). All other constituent levels at all monitoring sites were below the guidelines for human/livestock consumption and irrigation throughout the monitoring period. Salinity and sodicity levels were similar to those reported previously and TDS levels were lower than those reported previously for southern Alberta (Bolseng 1991, Bolseng 1992, Greenlee et al. 1993).

Nitrate: Nitrate concentrations were very low during most of the monitoring period (Table 1, Fig. 3), and were well below the Canadian water quality guidelines for human/livestock consumption (Table 2). The highest concentration was 7 mg L^{-1} on May 11 in the Battersea Drain return flow stream. Nitrate levels in all other water samples were below 1 mg L^{-1}. Nitrate levels were similar to those reported previously for southern Alberta (Bolseng 1991, Bolseng 1992, Greenlee et al. 1993).

Phosphate: Phosphate was not detected at the inflow and outflow sites of the irrigation block and was found infrequently at the other monitoring sites (Table 1).

Table 1. Salinity, sodicity, total dissolved solids, nitrate, phosphate, total and faecal coliform levels from LNID sites[1].

Monitoring Site	EC^2	SAR^2	TDS^2	NO_3-N^2	PO_4-P^2	Total Coliforms	Faecal Coliforms
	$ds\ m^{-1}$		$mg\ L^{-1}$			count $100\ ml^{-1}$	
Inlet Keho Lake	0.30 (0.02)	0.27 (0.11)	162 (16)	0.02 (0.07)	0.005 (0.02)	423 (503)	34 (51)
Outlet Keho Lake	0.34 (0.03)	0.56 (0.14)	189 (20)	0.006 (0.03)	0.003 (0.01)	70 (58)	41 (43)
Block Inflow (Site 4)	0.35 (0.03)	0.60 (0.13)	196 (25)	0.01 (0.04)	0	1070 (3034)	73 (68)
Block Outlfow (Site 5)	0.35 (0.03)	0.61 (0.14)	197 (26)	0.02 (0.09)	0	1078 (1630)	571 (1361)
Battersea Drain Return Flow	0.39 (0.05)	0.68 (0.16)	241 (36)	0.32 (0.05)	0.001 (0.004)	605 (589)	250 (272)

[1] Mean values, with standard deviation in parenthesis.

[2] EC = electrical conductivity, SAR = sodium adsorption ratio, TDS = total dissolved solids, NO_3 -N = nitrate nitrogen, PO_4-P = phosphate phosphorus.

Concentrations were extremely low and were consistently below the maximum desirable concentration of 0.10 mg L^{-1} for flowing water (EPA 1976). The highest value found was 0.09 mg L^{-1} in the Keho Lake inlet on October 5.

Total and Faecal Coliforms: Total and faecal coliform levels showed extreme fluctuations during the monitoring period. Average values were consistently above the Canadian water quality guidelines for human/livestock consumption, and were often above the guideline for irrigation (Table 1, Fig.3, Table 2).

Trace Elements: Trace element levels were below detection limits during most of the monitoring period, with the exception of copper (data not shown). The cadmium concentration was below the detection limit at all sites throughout the monitoring period. Most trace elements detected were at very low concentrations, and copper was found on most sampling dates at all sites. The highest concentration of copper was 0.030 mg L^{-1} in the Battersea Drain return flow stream on October 11. A concentration of 0.01 mg L^{-1} of lead, equal to the Canadian water quality guideline for human consumption (Table 2), was found in the Keho Lake inlet on July 27. All other trace element levels were below the guidelines for human/livestock consumption and irrigation. Maximum levels of arsenic, lead and

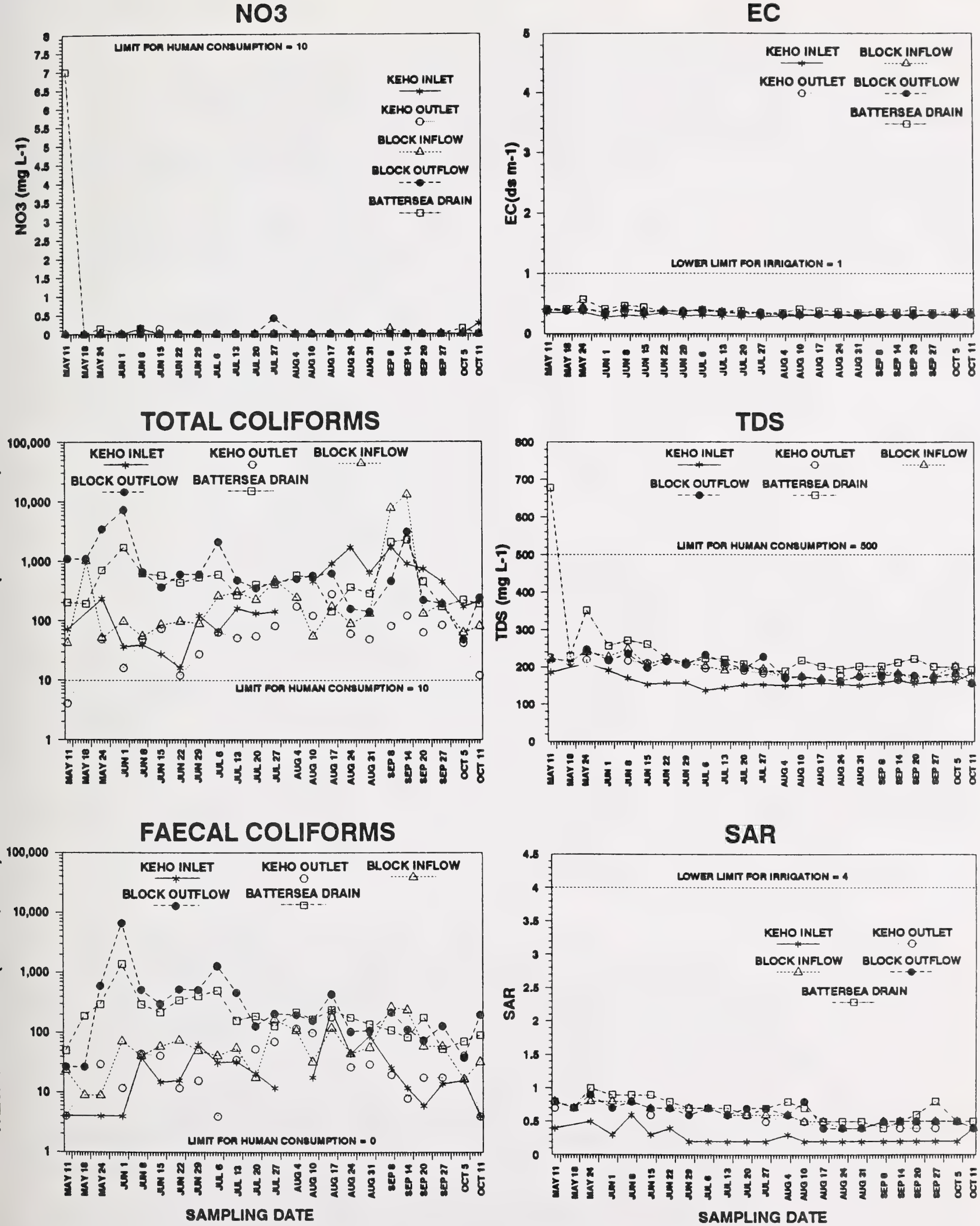


Figure 3. Seasonal salinity, sodicity, total dissolved solids, nitrate, total and faecal coliform levels from LNID sites.

Table 2. Canadian water quality guidelines.[1]

Parameter	Human Consumption	Livestock Consumption	Irrigation
EC (ds m^{-1})	na[2]	5	<1 - 2.5
SAR	na	na	<4 - 9
		$mg\ L^{-1}$	
TDS	500	3000	500 - 3500
NO_3	10	100	na
Arsenic	0.025	0.5	0.1
Cadmium	0.005	0.02	0.01
Copper	1.0	Cattle 1.0 Sheep 0.5 Swine & Poultry 5.0	0.2
Lead	0.01	0.1	0.2
Mercury	0.001	0.003	nrg[2]
Selenium	0.01	0.05	0.02
		count 100 ml^{-1}	
Total Coliforms	10	10	1000
Faecal Coliforms	0	0	100

[1] CCREM 1987 and updates, Alberta Agriculture 1992, FPSDW 1993.
[2] na - not applicable, nrg - no recommended guideline.

selenium were similar to those reported previously; and maximum levels of cadmium were lower than those reported previously by Bolseng (1991, 1992) for southern Alberta. Maximum levels of arsenic, cadmium, copper and lead were lower than those reported previously; and maximum levels of selenium were higher than those reported previously by Greenlee et al. (1993) for southern Alberta.

BRID

Salinity, Sodicity and TDS: Average salinity levels increased between the inlet of McGregor Lake and the outlet of Little Bow Lake, increased slightly between the inflow and outflow sites of the irrigation block, and did not change between the block outflow site and the New West Coulee return flow stream (Table 3, Fig. 4, Fig. 5). Average SAR levels more than doubled between the inlet of McGregor Lake and the

Table 3. Salinity, sodicity, total dissolved solids, nitrate, phosphate, total and faecal coliform levels from BRID sites.[1]

Monitoring Site	EC^2	SAR^2	TDS^2	NO_3-N^2	PO_4-P^2	Total Coliforms	Faecal Coliforms
	ds m^{-1}		mg L^{-1}			count 100 ml^{-1}	
Inlet McGregor Lake	0.31 (0.02)	0.28 (0.11)	190 (17)	0.43 (0.14)	0	662 (971)	29 (45)
Outlet Little Bow Lake	0.41 (0.02)	0.63 (0.10)	227 (26)	0.10 (0.38)	0.01 (0.04)	965 (2131)	25 (44)
Block Inflow (Site 3)	0.40 (0.02)	0.68 (0.09)	258 (38)	0.59 (0.55)	0.007 (0.02)	249 (545)	33 (25)
Site 4	0.54 (0.06)	0.70 (0.08)	340 (47)	0.43 (0.30)	0.05 (0.06)	1040 (724)	108 (114)
Site 5	0.44 (0.03)	0.69 (0.05)	261 (19)	0.21 (0.07)	0.02 (0.06)	996 (1329)	348 (890)
Site 6	0.41 (0.03)	0.70 (0.08)	240 (24)	0.18 (0.09)	0.006 (0.03)	565 (872)	73 (59)
Site 7	0.42 (0.03)	0.69 (0.08)	237 (21)	0.03 (0.08)	0.002 (0.009)	769 (647)	159 (198)
Block Outflow (Site 8)	0.43 (0.02)	0.70 (0.10)	246 (18)	0.05 0.10	0	1396 (1928)	101 (77)
New West Coulee Return Flow	0.43 (0.02)	0.73 (0.10)	242 (16)	0.02 (0.05)	0.001 (0.007)	1175 (857)	240 (276)

[1] Mean values, with standard deviation in parenthesis.
[2] EC = electrical conductivity, SAR = sodium adsorption ratio, TDS = total dissolved solids, NO_3 -N, = nitrate nitrogen, PO_4 -P = phosphate phosphorus.

outlet of Little Bow Lake, increased slightly between the block inflow and outflow sites and increased slightly in the New West Coulee return flow stream. Average TDS concentrations increased between the inlet of McGregor Lake and the outlet of Little Bow Lake, decreased slightly between the block inflow and outflow sites, and showed a further slight decrease in the New West Coulee return flow stream. The highest EC and TDS values occurred at site 4 in the irrigation block. TDS concentrations exceeded the Canadian water quality guideline for human consumption (Table 2) at the block inflow site and at site 4 on May 10 (796 and 668 mg L^{-1}) respectively. All other constituent levels were below the guidelines for human/livestock consumption and irrigation throughout the monitoring period. EC levels were similar to those reported previously; and SAR and TDS levels were lower than those reported previously for southern Alberta (Bolseng 1991, Bolseng 1992, Greenlee et al. 1993).
<u>Nitrate:</u> Nitrate levels were well below 1 mg L^{-1} for most of the monitoring period

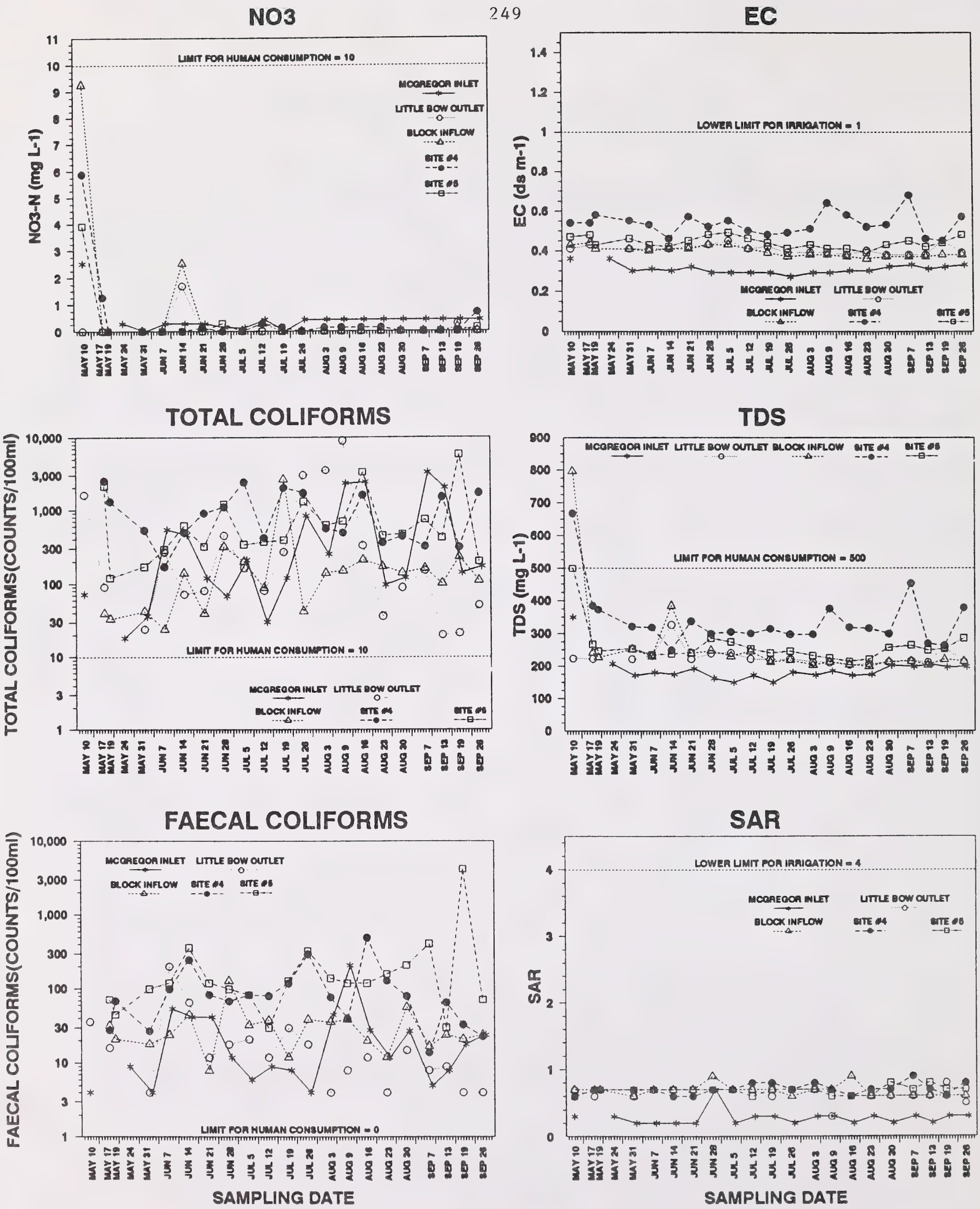


Figure 4. Seasonal salinity, sodicity, total dissolved solids, nitrate, total and faecal coliform levels from the McGregor Lake inlet, the Little Bow Lake outlet, the BRID Block inflow site and the BRID Block sites 4 and 5.

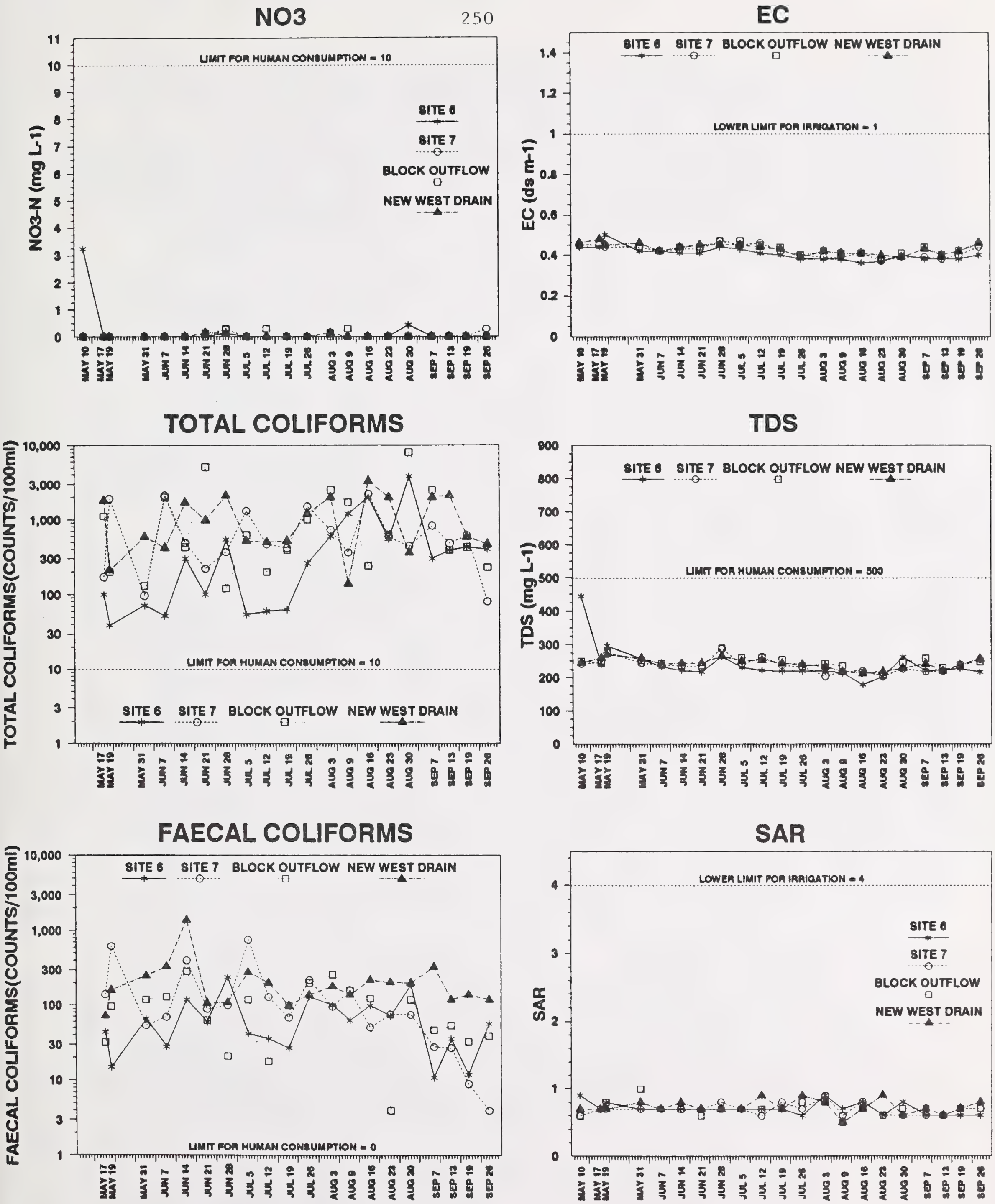


Figure 5. Seasonal salinity, sodicity, total dissolved solids, nitrate, total and faecal coliform levels from the BRID Block sites 6 and 7, the BRID Block outflow site and the New West Coulee return flow stream.

(Table 3, Fig. 4, Fig. 5), and were consistently below the Canadian water quality guidelines for human/livestock consumption (Table 2). The highest average nitrate concentrations occurred at the block inflow site, and the lowest average concentrations were found in the New West Coulee return flow stream. The highest nitrate values were detected on May 10, and ranged from 2.52 mg L^{-1} at the head of McGregor Lake to 9.25 mg L^{-1} at the block inflow site. Nitrate levels were higher than those reported previously for southern Alberta (Bolseng 1991, Bolseng 1992, Greenlee et al. 1993).

Phosphate: Phosphate was not detected during the monitoring period at the inlet of McGregor Lake and at the outflow site of the irrigation block (Table 3). Very low levels were found infrequently at the other sites. Concentrations slightly above the maximum desirable level of 0.10 mg L^{-1} for flowing water (EPA 1976) were detected on two occasions in the outlet of Little Bow Lake; on five occasions (four consecutive) at site 4; and on two consecutive occasions at site 5.

Total and Faecal Coliforms: Total and faecal coliform levels showed extreme fluctuations throughout the monitoring period. Average values were consistently well above the Canadian water quality guidelines for human/livestock consumption, and often above the guideline for irrigation (Table 3, Fig. 4, Fig. 5, Table 2).

Trace Elements: Trace element levels were below detection limits for most of the monitoring period, with the exception of copper (data not shown). The cadmium concentration was below the detection limit at all sites throughout the monitoring period. All trace elements detected were at very low concentrations, and copper was found on most sampling dates at all sites. A lead concentration of 0.023 mg L^{-1}, slightly above the guideline of 0.01 mg L^{-1} for human consumption (Table 2), occurred at site 5 on May 10. All other constituent levels were below the guidelines for human/livestock consumption and irrigation. Maximum levels of arsenic and lead were similar to those reported previously; maximum levels of cadmium were lower than those reported previously; and maximum levels of selenium were higher than those reported previously for southern Alberta by Bolseng (1991, 1992). Maximum levels of arsenic, cadmium, copper and lead were lower than those reported previously; and maximum levels of selenium were higher than those reported previously for southern Alberta by Greenlee et al. (1993).

Impact of Irrigation Return Flow

The impact of irrigation return flow water on receiving rivers is diminished by the dilution effect. This ranged from 47 to 316 times in the Oldman River (LNID) and from nine to 59 times in the Bow River (BRID) (Table 4). Other processes that reduce constituent concentrations in receiving streams and major water bodies to lower levels than those in edge-of-field runoff include sedimentation, vegetative trapping and degradation in transport (Leonard 1990).

Table 4. Mean daily water discharge ($m^3 S^{-1}$) in return flow streams and rivers during 1994.[1]

Month	Battersea Drain Return Flow	Oldman River near Lethbridge	Dilution Factor	New West Coulee Return Flow	Bow River near the mouth	Dilution Factor
May	0.599	189	316	1.72	101	59
June	0.515	121	235	3.25	186	57
July	0.611	28.8	47	3.38	54.5	16
August	0.508	30.4	60	2.21	29.2	13
September	0.551	26.5	48	2.26	19.7	9
October	0.378	32.0	85	0.500	22.1	44

[1] Preliminary data from Environment Canada, Environmental Monitoring and Systems Branch, Monitoring Operations Division, Water Survey of Canada, Calgary, Alberta

PRELIMINARY CONCLUSIONS

The quality of water at the inlet and outlet of an irrigation reservoir (Keho Lake), at the inlet of a second reservoir (McGregor Lake), at the outlet of a third reservoir (Little Bow Lake), in two irrigation blocks (LNID and BRID) and in two irrigation return flow streams in southern Alberta (Battersea Drain and New West Coulee) was generally found to be excellent for human/livestock consumption and irrigation. Exceptions were the levels of total and faecal coliforms, which fluctuated widely throughout the monitoring period at all monitoring sites. Total and faecal coliform levels were consistently above the Canadian water quality guidelines for human/livestock consumption and often above the guideline for irrigation.

Slight increases in salinity and TDS concentrations were observed and SAR levels doubled between the inlet and outlet of the irrigation reservoirs. Salinity, sodicity and TDS levels showed small fluctuations in both irrigation blocks and in both return flow streams. TDS concentrations exceeded the Canadian water quality guideline for human consumption on the initial sampling day of the season at three of 16 sampling sites. All other levels of these three constituents were below the guidelines for human/livestock consumption and irrigation at all sites throughout the monitoring period.

Nitrate and phosphate concentrations were very low at all sites for most of the monitoring period. The highest nitrate levels occurred on the initial sampling day of the season, and concentrations were consistently below the Canadian water quality guidelines for human/livestock consumption. Phosphate concentrations were generally below the maximum desirable level for flowing water. Concentrations slightly above this level were detected occasionally at the outlet of Little Bow Lake

and at three monitoring sites in the BRID block (sites 4, 5 and 6). Phosphate was not detected in the LNID block, at the head of McGregor Lake and at the BRID block outflow site.

Levels of most trace elements were either below detection limits or were very low throughout the monitoring period. Copper was found at very low concentrations on most sampling days at all monitoring sites, and cadmium was not detected during the monitoring period. A lead concentration equal to the Canadian water quality guideline for human consumption was found at the Keho Lake inlet site on one sampling date, and a lead concentration slightly above this level occurred on the initial sampling day of the season at two sites in the BRID block (sites 5 and 6). All other trace elements detected were at levels below the guidelines for human/livestock consumption and irrigation throughout the monitoring period.

The impact of irrigation return flow water on receiving rivers was slight. Constituent levels at river monitoring sites (data not shown) were generally lower than or similar to constituent concentrations at irrigation reservoir monitoring sites, irrigation district monitoring sites and return flow stream monitoring sites.

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Bow River Irrigation District

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WATER MANAGEMENT

WATER CONSUMPTION UNDER ROTATIONAL GRAZING

W. Sawchuk, N. MacAlpine, K. Williamson, B. Caskey, G. Rock[1]

Introduction

The Prestage Pasture project was initiated in 1991 and for the last four years, the 64 ha of pasture has been the site for an integrated rotational grazing study. Cattle performance under rotational grazing, pasture renovation, development of water, protection of the water source with solar powered pumping, insect control and the economics of forage production versus grain production are a sample of some of the trials carried out on this project.

The objective of the water and weather portion of this project was to estimate water consumption and factors affecting intake in grazing cattle. Other portions of this project included water consolidation, within a small watershed of rolling topography, to provide a good quality water supply.

The Battle River Research Group (1994) has led the studies on the grazing management system incorporating a rotational grazing system with no fixed field size. Pasture rejuvenation using rest, fertilizers and a extended grazing system are some of the strategies tested at the Prestage Pasture Project. George Rock, Farm Management Specialist, AAFRD, compared the economic performance of the forage/livestock production system versus grain production on an adjoining parcel of land. The project in 1994 studied the adaptation of feeder cattle to an alfalfa/brome grass pasture that did not cause bloat in Bob Prestage's cow/calf operation. Ali Khan, Livestock Pest Control Specialist, AAFRD, has investigated different methods of effective and economical insect pest controls for cattle in combination with pasture watering and rotational grazing systems.

Ken Williamson, Reg. Agric. Eng. Technologist, AAFRD, has coordinated the efforts of the County of Camrose and the Alberta Environmental Centre to evaluate the water management component of this demonstration. His study has compared the water quality in a direct access dugout to the water quality in the Prestage dugout with solar pumping and no access by cattle.

METHOD

In 1991 on a rolling 64 hectares pasture just west of Camrose, several wet depressional areas and potholes were consolidated into two dugouts by means of open ditches (grass waterways) and buried plastic tubing. The design of the dugouts were based on a two year water supply for drought years. Dugout locations were selected to compliment the field plan

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for the grazing system. These dugouts were fenced off from direct cattle access. A solar pump and water trough were installed, close to the west dugout, to provide each pasture area access to the water trough.

The fenced dugouts at the Prestage pasture never had cattle drinking directly from them. So it was an ideal site to compare water quality to a pasture dugout that allowed cattle free access to the dugout. A direct access dugout was located close by in a neighbouring pasture. It was similar to the fenced dugout in size and age. The direct access dugout supplies water to a herd of 200 head of cattle. The watershed for the fenced dugout is entirely under forage production while the direct access dugout's watershed is primarily pasture land with a small portion in cereal crop production.

Water samples were taken once per month from May to October from 1992 to 1994, from both dugouts at a point about three metres from the bank and about thirty centimetres below the water surface. Samples were analyzed at the Alberta Environment Centre in Vegreville. Tests included were routine chemical, microbiological, and nutrient analysis.

The weather station was installed by the fenced dugout in June 17, 1992. Instruments at the station consisting of a tipping bucket rain gauge, a temperature-relative humidity senor and a manual rain gauge. A flow meter also recorded the amount of water pumped to the supply trough. A datalogger recorded total daily rainfall and daily maximum, minimum and average air temperature and relative humidity. The water volume pumped was recorded in hourly and daily totals. The daily water consumption was determined from this data. The evaporation losses from the trough were considered negligible, and no adjustments were made for these losses.

For this study the animal units were based on weight, 1000 pounds equal to one animal unit (AU). For 1992 there was twenty five Black Angus cows, twenty six calves, ten heifers and one bull, for a total of 42.5 AU at the beginning of the season. They were in the pasture from May 16 to September 9, 1992. In 1993, there were forty four Angus cows, forty two calves, and one bull, for a total of 58.6 AU. The cows were on the pasture from May 18 to October 31, 1993. The calves were on the pasture from May 18 to September 14, 1993. In 1994, there was a total of 127 steers for a total of 85 AU on the pasture from May 28 to August 15, 1994.

The fenced dugout and the watering facility were centrally located with respect to the pastures. The maximum distance the cattle had to walk to the water trough was approximately 700 m, and the minimum distance was 10-15 m. There was no shade available in the pastures.

The effect on water consumption from the maximum and average temperature, maximum, minimum and average relative humidity, and time (days), which reflects animal growth as the season progressed, was determined by stepwise multiple regression using software from the Statistical Analysis System Institute, Inc (1988). The analyses were done across all months and within each month for each year.

Livestock were weighed in the spring and fall of 1992, 1993 and 1994. The cows were also body conditioned scored (BCS) for 1992 and 1993. In 1994, BCS was not done because the herd was steers only. Temporary electric fencing was put up every year to subdivide the quarter into a different number of pastures each year depending on the herd size. Forage production was determine by clippings taken before the cattle were moved into a new pasture.

The herd was monitored for signs of bloat, especially when they were grazing the alfalfa fields during June and July. As part of the bloat study, Agriculture and Agri-Food Canada's Kamloops Research Station donated three older fistulated steers to the project in 1994. These Jersey steers are prone to alfalfa bloating and have been used in previous bloat trials. A nylon bag digestibility trial was conducted in the fall of 1994 using the three steers. The details on these results will be available in a Farming for the Future report that will be available from the Alberta Agriculture Research Institute in March 1995.

RESULTS

Water Consumption Rates on Pasture

In 1992, the average water consumption was 1933.9 litres per day or 45.5 litres per day per AU (1933.9/42.5) (Ali et al 1994). The three year average for cattle on the Prestage pasture is 46 litres per day per AU. This is consistent with other studies quoted by Ali et al (1994) which range from 42 to 48 litres per day per head.

Weather Factors Influencing Water Consumption

An analysis using stepwise linear regression was carried out to find the correlation between daily maximum and average air temperatures and daily maximum and average relative humidities to daily water consumption by the cattle for 1992, 1993 and 1994. For 1992, the daily average relative humidity was the most significant factor. For each percentage decrease in average relative humidity, daily water consumption increased by 26.8 litres for 42.5 AU (0.63 litres per AU). For a degree increase in maximum temperature, daily water consumption increased 31.8 litres for 42.5 AU (0.75 litres per AU). For each day through the season, daily water consumption increased by 5.8 litres for 42.5 AU (0.14 litres per AU). Average relative humidity, maximum temperature and time through the season accounted for 40.4% of the variation in daily water consumption by cows with calves and heifers in 1992.

In 1993, maximum temperature was the major factor influencing water consumption with time through the season (days) and average relative humidity being secondary factors. The temperatures in 1993 higher than the norm. In 1994, daily water consumption again was principally influenced by the average relative humidity. This recurrence is significant since the herd was steers in contrast to the cow/calf herds of 1992 and 1993. 1994 was within the norm for monthly temperatures from May through to September. June 1994 rainfall was 55 mm above the average. Rainfall for July, August, and September 1994 were all below the thirty year average.

The linear regression equations relating daily water consumption to weather factors for each year are:

1992 WC = 2891.6 - 26.8 AVERH + 31.8 MAXTEMP + 5.8 DAYS
MODEL R = 40.4 % (Ali et al 1994)

1993 WC = 1314.8 + 60.3 MAXTEMP + 13.7 DAYS - 19.9 AVERH
MODEL R = 42.3 %

1994 WC = 9281.4 - 98.0 AVERH + 26.3 TOTDAY
MODEL R = 55.6 %

Timing of Watering

Figures 1, 2 and 3 summarize the time of day that cattle drank during the summers of 1992, 1993 and 1994 respectively. Night was classified from 12 midnight to 6 am, morning from 6 am to noon, afternoon from noon to 6 pm and evening from 6 pm to midnight. Even though the herds were different in 1992 and 1994, the pattern of watering is the same, primarily in the morning and afternoon. 1993 is significantly different with night time watering dominating. We do not have an explanation for this behaviour by the cow/calf herd other than to note that 1993 weather was hotter than the other two years. The incidents of night time watering were clustered predominately at 4 to 5 am, about daybreak but there were a significant number of waterings at 1 and 2 am. Significantly, the cattle established this behaviour at the start of the grazing season in 1993 and did not vary it significantly as the summer went on.

Water Quality Impacts of Direct Access by Cattle into Dugouts

Phosphorous is usually considered the major nutrient problem in surface water. High phosphorous levels normally result in problem algae growth. Total phosphorous levels, likely from manure, in the direct access dugout were always higher than in the fenced dugout. The phosphorous levels by the end of the project were approximately three times higher in the direct access dugout than in the fenced dugout. Even the fenced dugout had five to ten times the maximum guideline level of phosphorous during the last two years of the study. This may have been due to manure runoff from the trough area or high phosphorous blend fertilizer washing off from the pasture.

During the first year of the study the water in the fenced dugout was clean and clear. It had what appeared to be a filamentous algae growing among the aquatic plants. This pattern started to change in September 1992, when some blue-green (grass clippings) started to show up in one edge of dugout. This coincided with the higher phosphorous levels that were recorded. This type of algae could be toxic to cattle if ingested when watering.

The direct access dugout was murkier and had a extremely high nutrient levels, but never produced a significant algae bloom. The reason for this is unknown. It could be from algae eating zooplankton or possible herbicide residues from the watershed. The direct access dugout also had significantly higher levels of faecal strepti-cocci and faecal coliform, signatures of

manure fouling the dugout water (Battle River Research Group 1994).

The fenced dugout is still in perfect physical condition after three years of use while the direct access dugout is badly trampled and will probably need to be cleaned out in a few years.

The pipeline and grass waterways constructed to consolidate the low areas are holding up well to activities in the pasture. The west dugout at the Prestage pasture has supplied all the needed stock water every year. The east dugout has not been used and is a reliable reserve for drought conditions.

CONCLUSIONS

While temperature is the primary determinant of changing the daily water consumption in locations with hot summers, in the cooler and drier summers of Alberta with wide daily fluctuations in temperature, daily water consumption is more dependent on changes in relative humidity. Daily water consumption has been within the norm reported by other researchers (46 litres (10 Imp. gallons) per AU).

Water quality from a nutrient and bacteriological basis indicates that direct access dugouts have higher nutrient levels and higher risk of disease transmission than dugouts with restricted access. However, in this study, the higher nutrient loads in the direct access dugout did not translate into greater algae blooms. In fact, the controlled access dugout developed a risk of blue-green algae problems when its phosphorus concentrations became large enough to support algae growth. Routine chemical analysis from the two dugouts showed little differences. A routine chemical test may be a poor indicator of water quality problems with dugouts.

The water consolidation into two dugouts has allowed the pasture to be grazed intensively, by a larger cattle herd, without a water shortage. Electric fencing around both dugouts at the fenced sites has maintained their structure which will increase the life of both.

Bloat was not a cause of death in the four years of the project. Management is the key to avoiding bloat problems on alfalfa pasture.

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Figure 1. Pumping Time (1992)

Total = 208,465.27 litres

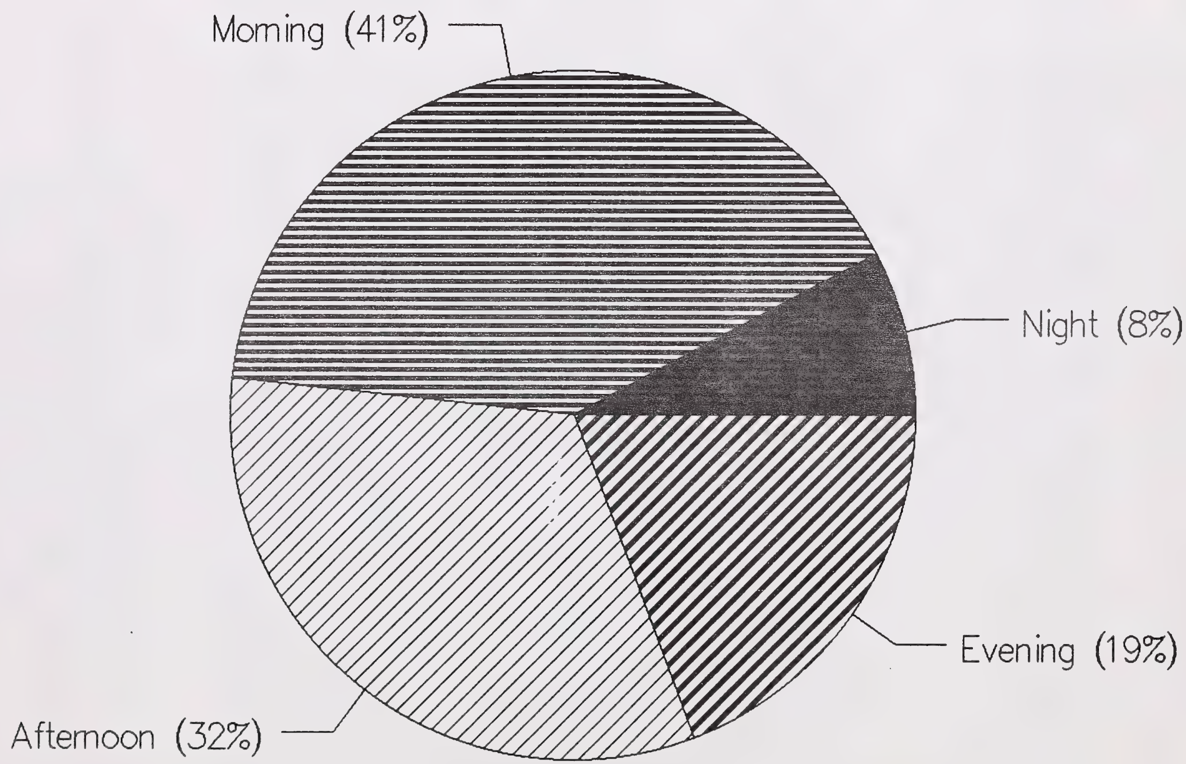

Figure 2. Pumping Time (1993)

Total = 286,843.73 litres

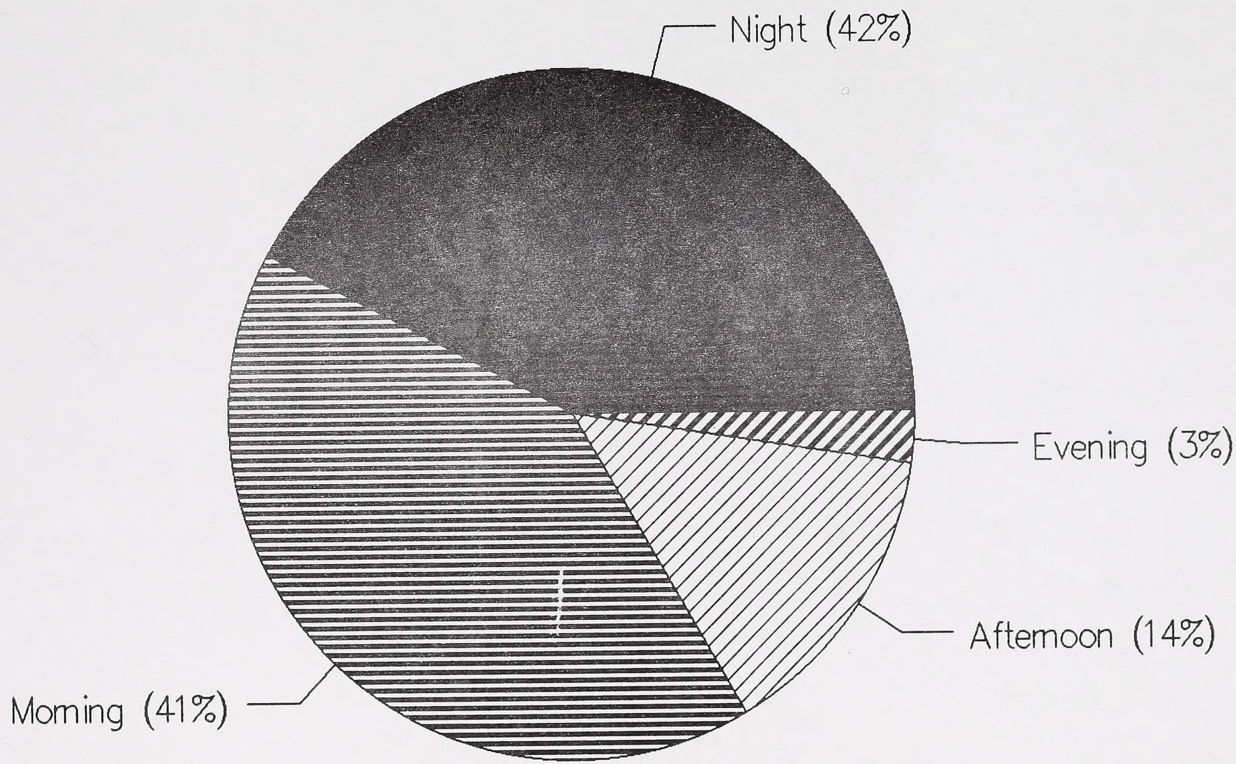

Figure 3. Pumping Time (1994)

Total = 204,166 litres